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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

LEVEL II

LANDING VEHICLE ASSAULT (LVA) MOTION CHARACTERISTICS IN OBLIQUE SEAS

~~SEAS~~ AND COASTAL SWELLS

by

Ralph Stahl

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Ship Performance Department

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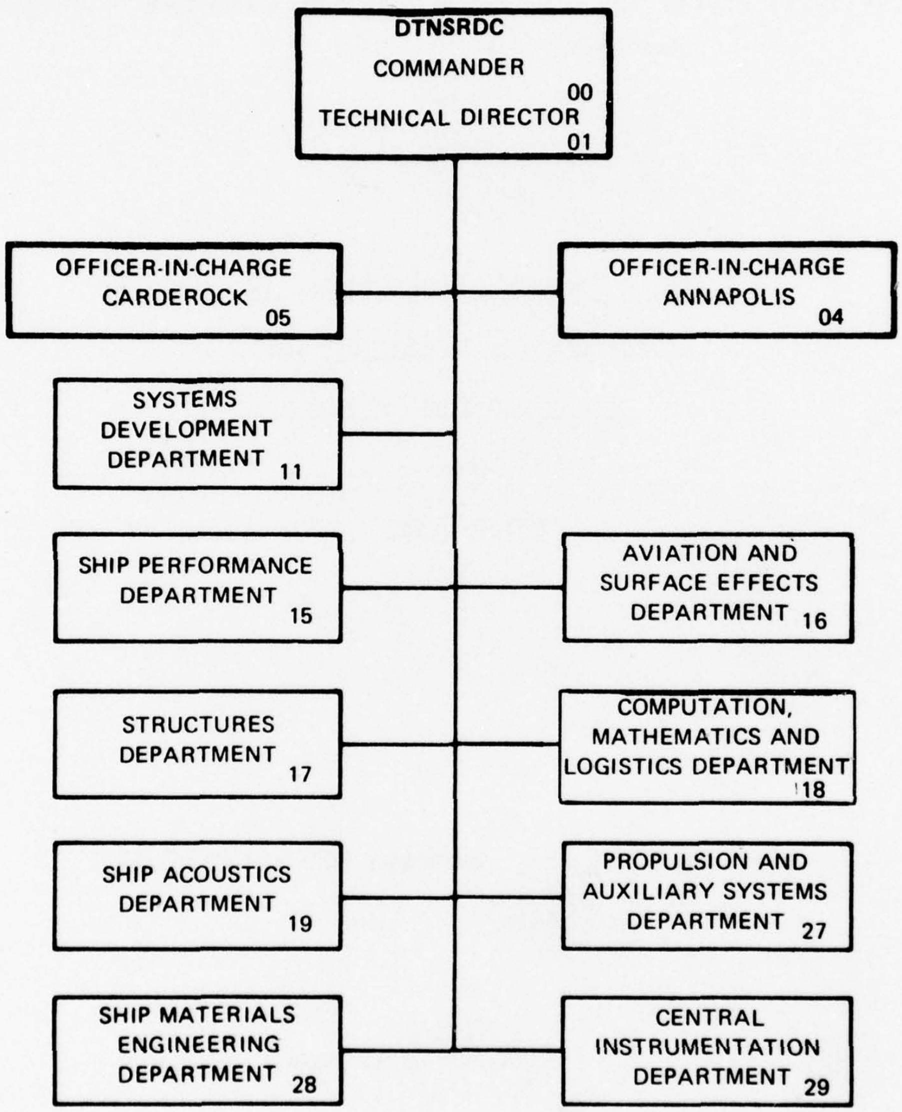

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Model experiments were conducted to investigate the seakeeping characteristics of a heavily loaded (55,000 lb.) Landing Vehicle Assault (LVA) planing hull. The vehicle under consideration has a flat-bottomed, zero deadrise angle planing surface with an adjustable full span transom stern flap and optional chine flaps. Experiments on the free-running 1/12 scale model, both with and without chine flaps were conducted at various speeds in simulated oblique irregular sea and coastal swell conditions. The intent of the investigation

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was to determine the craft habitability and safety of personnel as well as craft controllability. This information is presented herein in terms of wave induced craft vertical accelerations in standard one-third octave frequency bands. Additional plots are given for pitch, heave and roll accelerations. Vehicle responses to a 10 second period (full scale) swell are given in tabular form as acceleration transfer functions.

Vertical acceleration levels at the bow and LCG were compared with MIL standards for maintaining personnel proficiency for one-hour. The results generally indicate the LVA accelerations to be within or at least marginally within acceptable levels. Some exceptions, particularly at the craft's bow, were noted in head and bow waves.

TABLE OF CONTENTS

	Page
ABSTRACT	1
ADMINISTRATIVE INFORMATION	2
INTRODUCTION	2
DESCRIPTION OF THE PROTOTYPE AND MODEL	3
EXPERIMENTAL PROCEDURE AND DATA ANALYSIS	4
PRESENTATION AND DISCUSSION OF EXPERIMENTAL RESULTS	8
PERFORMANCE IN IRREGULAR WAVES	10
PERFORMANCE IN COASTAL SWELLS	12
HABITABILITY ESTIMATES IN A SEAWAY	13
CONCLUSIONS	16
ACKNOWLEDGMENTS	18
REFERENCES	18

LIST OF FIGURES

1 - LVA Hull . . . .

2a - Typical DTNSRDC MASK Facility Irregular Wave Spectra with Comparative Pierson-Moskowitz Wave Spectrum at Model Scale for a Sea State 2 . . . .

2b - Typical DTNSRDC MASK Facility Irregular Wave Spectra with Comparative Pierson-Moskowitz Wave Spectrum at Model Scale for a Sea State 3 . . . .

2c - Typical DTNSRDC MASK Facility Irregular Wave Spectra with Comparative Pierson-Moskowitz Wave Spectrum at Model Scale for a Sea State 4 . . . .

3a - Significant Pitch, Heave and Roll Accelerations versus Craft Heading for the Two Configurations of without and with Chine Flaps in a Sea State 2 . . . . . .

3b - Significant Pitch, Heave and Roll Accelerations versus Craft Heading for the Two Configurations of without and with Chine Flaps in a Sea State 3 . . . . . .

3c - Significant Pitch, Heave and Roll Accelerations versus Craft Heading for the Two Configurations of without and with Chine Flaps in a Sea State 4 . . . . . .

4a - Narrowband Vertical Acceleration Intensities versus Standard Center Frequency of one-Third Octave Bands at the Bow and CG for the LVA with and without Chine Flaps at 30 knots, Head Sea State 2 . . . .

4b - 30 knots, Bow Sea State 2 and Swell . . . .

4c - 15 knots, Bow Sea State 3 . . . .

4d - 5 knots, Bow Sea State 4 . . . .

4e - 30 knots, Beam Sea State 2 and Swell. . . . .

4f - 15 knots, Beam Sea State 3. . . . .

4g - 5 knots, Beam Sea State 4 . . . .

5a - Narrowband Vertical Acceleration Intensities versus Standard Center Frequency of the one-third Octave Bands at the Bow and CG for the LVA with and without Chine Flaps at 0 knots, Head Sea State 2 . . . .

LIST OF FIGURES (CONT.)

5b - 0 knots, Bow Sea State 2 and Swell . . . .

5c - 0 knots, Bow Sea State 3 and Swell . . . .

5d - 0 knots, Bow Sea State 4 and Swell . . . .

5e - 0 knots, Beam Sea State 2 and Swell. . . . .

5f - 0 knots, Beam Sea State 3 and Swell. . . . .

5g - 0 knots, Beam Sea State 4 and Swell. . . . .

6 - Sample Time Histories, Both Unfiltered and 100 Hz Filtered, of Bow Accelerations in a Head Sea State 2 at a Speed of 30 knots for the No Chine Flapped Craft. .

7 - Sample of Rudder Displacement of the LVA with Chine Flaps in Bow Seas. . . . .

LIST OF TABLES

1 - LVA Particulars . . . .

2 - LVA Irregular Wave Experiment Matrix . . . .

3 - LVA 10-Second Period Swells (Regular Wave) Experiment . . . . . .

4 - LVA Motion Responses to Coastal Swells (10 Second Period, 1.4 Degree Wave Slope) at Various Craft Speeds and Headings. . . . .

ABSTRACT

Model experiments were conducted to investigate the seakeeping characteristics of a heavily loaded (55,000 lb.) Landing Vehicle Assault (LVA) planing hull. The vehicle under consideration has a flat-bottomed, zero deadrise angle planing surface with an adjustable full span transom stern flap and optional chine flaps. Experiments on the free-running 1/12 scale model, both with and without chine flaps were conducted at various speeds in simulated oblique irregular sea and coastal swell conditions. The intent of the investigation was to determine the craft habitability and safety of personnel as well as craft controllability. This information is presented herein in terms of wave induced craft vertical accelerations in standard one-third octave frequency bands. Additional experimental results are given for pitch, heave and roll accelerations. Vehicle responses to a 10 second period (full scale) swell are given in tabular form as acceleration transfer functions.

Vertical acceleration levels at the bow and LCG were compared with MIL standards for maintaining personnel proficiency for one-hour. The results generally indicate the LVA accelerations to be within or at least marginally within acceptable levels. Some exceptions, particularly at the craft's bow, were noted in head and bow waves.

ADMINISTRATIVE INFORMATION

The study reported herein is in support of the Landing Vehicle Assault Program. The work was sponsored by the Naval Sea Systems Command, and was authorized under Task Area SF43411210, Task 19058, Work Unit No. 1120-008.

INTRODUCTION

The Landing Vehicle Assault (LVA) under consideration herein is a planing boat designed primarily to transport men and war material between off-shore stationed ships and beach or inland staging areas at relatively high speed. Because of the dimensional constraints and large loadings associated with its intended mission, hydrodynamic pressures on the LVA's planing surface are significantly greater than for conventional planing boats. From the various initial LVA design concepts under consideration, two versions were selected to be evaluated in clam water and in head waves (Ref 1)*. The chosen configurations were the inverted vee-bottom and flat-bottomed planing hulls. Added to the basic hulls were adjustable transom stern flaps and optional chine flaps. The overall dimensions and loadings for the two vehicles were identical. From these experimental investigations on scaled models, the model hcosen for further evaluation, particularly in oblique sea and coastal swell conditions, was the flat-bottomed planing hull with adjustable transom stern flaps. Using this basic design, seakeeping tests were conducted on a model both with and without chine flaps at various speeds and headings in simulated Sea States 2, 3, and 4 as well as a simulated coastal swell condition.

*References are listed on Page 17.

Due to weight and space limitations, the model was instrumented only with accelerometers from which the wave induced craft accelerations were obtained. This report contains a description of the LVA, a discussion of the experimental procedures, and the presentation and discussion of experimental results including the influence of chine flaps in craft motions.

DESCRIPTION OF THE PROTOTYPE AND MODEL

The prototype, as shown in the sketch of Figure 1, has a right cylindrical hull geometry with a zero-deadrise flat bottom extending forward from the transom stern for a distance of 0.8 LOA. From that point the surface curves up in a continuum. Hinged to the transom stern was an adjustable, full span flap having a full-scale chord of .79 meters (2.6 ft.) and a span of 3.35 meter 11.0 ft). The flap was hinged to the hull along the line of intersection of the flat bottom and the transom where flow separation would normally take place when planing without a flap. The transom stern flap angle is taken to be zero when the flap is oriented as a horizontal extension of the flat-bottom. A positive flap angle setting is defined to be a downward orientation of the flap from the zero degree setting. Optimal 0.76 m (2.5 ft.) span chine flaps when mounted provide a continuum sideward extension of the flat bottom. The chord or length of each flap was 4.6 m (15.1 ft) with the mid-chord located at midship. Further full-scale particulars are given in Table 1.

A 1/12 linearly scaled model constructed of fiberglass covered poly-urethane was ballasted in accordance to design specifications listed in Table 1. Experiments were conducted both with and without the chine flaps.

The seakeeping experiments performed on the LVA model required the model to be free in all six-degrees of freedom which necessitated a free running model. Steps were taken to outfit the model with a propulsion unit and a steering system. The propulsion unit consisted of a variable speed D.C. motor driving twin propellers via an appropriately designed reduction gear unit. Steering was provided by a single partially balanced rudder with a centerplane-located axis of rotation. Rudder actuation was provided by a servo-motor. Both propulsion and steering were remotely and manually controlled. Power for the propulsion motor, the rudder servo-motor and the control signals for the rudder were fed from the carriage to the model through a light, flexible umbilical cord.

EXPERIMENTAL PROCEDURE AND DATA ANALYSIS

Experiments on the self-propelled remotely controlled LVA model were conducted in the DTNSRDC Seakeeping and Maneuvering Basin over a simulated full-scale speed range of 5 to 30 knots in various unidirectional irregular wave and swell conditions at a number of headings as given in Tables 2 and 3 respectively. The chosen irregular sea conditions simulated were Sea States 2, 3, and 4. The simulated coastal swell had a full-scale period of 10 seconds with a 1.2 M (4.0 feet) wave height, which corresponds to a 1.4 degree wave slope. Such a wave is representative of swells observed along the California coast. Experiments were conducted at headings of β = 45, 90 and 135 degrees and 180 degrees which correspond to quartering, beam, bow and head seas. The head sea condition was run primarily for correlation with Stevens Institute of Technology (S.I.T.) (Ref. 1) experimental results. At both standstill and full-scale design speed of 30 knots, the model was tested in a simulated unidirectional Sea State 2 for all four headings, i.e.,

β = 45, 90, 135, and 180 degrees as well as in a simulated swell having a 10 second period (full scale) swell at heading of β = 45, 90 and 135 degrees. The craft's performance in these conditions is of prime importance since it was designed to operate at its full potential in coastal sea and swell conditions up to and including a Sea State 2 with minimal adverse effects on the occupants. Further evaluations were conducted with the craft at 15 knots (full scale) in a Sea State 3 and at 5 knots (full scale) in a Sea State 4 as well as at standstill in both sea states at the headings of β = 45, 90 and 135 degrees. To obtain a good data sample for statistical averages and spectral analysis in irregular wave experiments requires approximately 150 wave encounters. For this test program such a sample was attainable for all headings except quartering seas. At that heading the encounter frequency was generally so small as to necessitate a reduction in the number of wave encounters collected. This procedure was further justified by the comparatively insignificant wave induced craft accelerations in quartering seas.

Sample wave height spectra as generated in the DTNSRDC MASK Facility for the LVA experiments are presented in model scale in Figures 2a, b, and c representing Sea States 2, 3, and 4 respectively. The two spectra in each figure are a result of the different pneumatic wave generating systems used in the experimental program; one for model headings of 45, 135, and 180 degrees referred to as the "short bank" and the second for the heading of 90 degrees referred to as the "long bank". For reference, Sea States 2, 3, and 4 model scaled Pierson-Moskowitz wave height spectra are also shown. The nominal full scale significant wave heights typifying each of these spectra were 0.76, 1.40, and 2.10 m (2.5, 4.6, 6.9 feet).

With the proper ballasting to design specifications, experimental evaluations on the model were made both with and without chine flaps in accordance with the above outlined test matrix. The transom stern flap angle was set at 0 degrees for the model without chine flaps and a +2.5 degrees for the chine flapped model configuration. These transom stern flap angle settings were determined to be the optimum positions based on prior experimental LVA model results from Stevens Institute of Technology (S.I.T.).

With the experiment's intent of determining the seakeeping characteristics of the LVA, a self-propelled model was run unrestrained beneath the MASK facility's carriage at the desired heading and speed by manually controlling the rudder position and the propeller thrust. Data was collected for the following: wave height, carriage speed, four vertical accelerations and rudder displacement. Wave height was measured by an ultrasonic transducer located in such a position as to insure a signal free of craft generated waves for each heading. The four craft accelerations measured were the vertical accelerations at the bow, LCG, stern and at the starboard side. Each of the four accelerometers (with a nominal 1.0KHz natural frequency and acceleration ranges of ± 0.1 to 50G's/volt in 9 steps) were non-pendulous, linear, force balanced, servo transducers with axes parallel to the craft's vertical coordinate. With the axes of the bow, LCG, and stern accelerometers in the craft's centerplane, the bow accelerometer was 4.72 m (15.5 ft) (full scale) forward of the CG and the stern accelerometer was 2.56 m (8.4 ft) aft of the CG. The fourth accelerometer was located transversely 1.2 m (3.9 ft) to the starboard side and longitudinally at the LCG.

During the experiment all transducer signals were filtered by 6Hz, 6-pole Butterworth filters due to excessive noise content in the accelerometer signals. These signals representing wave height, carriage speed and the accelerations at the four locations were recorded in analog form on paper strip chart and on magnetic tape. Analysis was provided by an on-line digital computer which furthermore computed pitch accelerations using the bow and stern accelerometer signals and roll accelerations using the starboard and CG accelerometer signals.

The on-line computer analysis furnished either statistical averages or harmonic analyses of wave height and model responses as desired for a given test condition. The statistical averages obtained for all irregular wave experiments were the mean, standard deviation (σ) and ROOTQO's ($\sigma\sqrt{2}$). In addition to the statistical averages, one could also obtain spectral analyses of the various transducer signals, although this option was utilized primarily for checking due to the time involved. For model responses in regular waves, harmonic analysis furnished the measured wave period, ROOTQO ($\sigma\sqrt{2}$), the amplitude and phase angle of the fundamental, and the first two harmonics, as well as the transfer functions of each signal. Rudder angle was monitored for the latter portion of the experimental program by recording the angle in analog form on paper strip chart.

Post-experimental data processing was primarily to obtain the one-third octave frequency band plots. The two locations of prime interest with regard to vertical accelerations were at the bow and the craft's CG for which the signals of the correspondingly located accelerometers were utilized.

Color 16 mm silent motion pictures to be viewed at the normal projector speed of 24 frames per second were taken of each test condition in both full-scale time, which simulated the prototype, and at model scale time. From this, a 19.5 minute long film was compiled consisting of a few scenes of the model being tested (model scale time) followed by simulated full scale samples of the LVA's performance for each test condition and for each of the two craft configurations. All sequences were appropriately titled so as to make the film self-explanatory. In addition to the taking of motion pictures during the experiments, a few 35 mm color slides were made. Furthermore, all test runs were recorded on video-tape in black and white.

PRESENTATION AND DISCUSSION OF EXPERIMENTAL RESULTS

All experimental results presented in this report, with the exception of the sample simulated wave spectra, have been extrapolated by Froude scaling to full-scale values. Significant wave induced craft accelerations as presented in Figures 3a, b, and c as well as significant wave height were derived by multiplying the standard deviation, σ, by a factor of 4. One-third octave band frequency analysis of the craft accelerations are given in Figure 4a through 5g. Data shown in these figures do not extend beyond 1.6 Hz full scale which corresponds to the 6 Hz cut-off frequency (3 db attenuation point) of the filters used during the recording and computer analysis of model data, except for the 30 knot head Sea State 2 no chine flap case, shown in Figure 4a, which was filtered at 50 Hz (14.4 Hz full scale). Unfortunately the 6Hz cut-off frequency was slightly lower than that required to accurately resolve all of the very high frequency content of the 30 knot head sea runs, and some small error may have been introduced into the estimates of the significant values at this speed.

The error introduced in the accelerations by the use of the 6 Hz filters was determined from the 50 Hz filtered 30 knot head Sea State 2 no chine flap case which is also the condition with the highest expected wave encounter frequencies. The significant peak to peak oscillations obtained in terms of full scale are tabulated below.

	UNITS	6Hz FILTER	50 Hz FILTER
WAVE HEIGHT	METERS (FEET)	0.733 (2.234)	0.823 (2.510)
BOW ACCELERATION	G	2.316	2.865
CG "	G	1.139	1.356
STERN "	G	0.888	0.932

Since this 30 knot head Sea State 2 condition has the highest encounter frequencies it should have the greatest error. All remaining conditions having lower wave encounter frequencies would be expected to have correspondingly smaller errors. For the above condition the wave frequency corresponding to a 6Hz encounter frequency (model scale) is 1.28 Hz (model scale). The test condition with the next lower encounter frequencies, the model advancing at the same speed and sea state at 135 degree heading (bow seas), would have a 4.62 Hz encounter frequency corresponding to the same 1.28 Hz wave frequency. Although a correction factor can be determined for the reanalyzed case, correction factors for the bow Sea State 2, 30 knot craft speed condition are less easily determinable. Consequently, the wave induced craft accelerations for the head and bow Sea State 2, 30 knot speed conditions presented in Figure 3 are uncorrected. The other speed and sea state conditions at 135 degree heading as well as all remaining test condition results were much less affected by the 6Hz transducer signal filtration due to low wave encounter frequencies.

As previously indicated, the one-third octave bands of LVA acceleration levels presented in Figures 4a and 4b have a cut-off frequency band at 1.6 Hz (full scale) due to significant signal attenuation at the higher frequency bands as a result of the 6 Hz filtration during the experiment. Extrapolations though can be made with the use of the reanalyzed 30 knot, head Sea State 2 no chine flap case shown in Figure 4a. For the conditions in Figures 4c through 4g and for all zero speed conditions, acceleration levels in the center frequency bands of 2.0 Hz and greater are minimal both with respect to the peak intensity and to the allowable intensity levels.

Impacting, which occurred in head and bow seas, was not discernible in the power spectrum from the reanalyzed test condition even though a scan rate of 500 samples/second (a sample every 0.002 seconds) was sufficient to describe an impact having an approximate duration of 0.03 second (model scale) (0.11 seconds full scale, (see Figure 6)). This is attributed to the averaging process in the analysis. That is, the energy of the impacts may be considerable but in averaging over the entire run the energy attributed to the impacts is insignificant.

PERFORMANCE IN IRREGULAR WAVES

For the irregular wave experiments, significant pitch, heave, and roll accelerations versus craft heading for the two craft configurations are given in Figures 3a, b, and c for Sea States 2, 3, and 4 respectively. As previously mentioned, experiments in head seas (180 degree headings) were limited to Sea State 2 where the results compare well with those obtained at Stevens Institute of Technology. In Figure 3a significant pitch and heave accelerations were greatest in head and bow waves at a craft speed of 30 knots. Significant pitch and heave accelerations of 7.4 degrees/sec^2 and 1.9 G's can be expected at both headings with the chine flaps where the

measured pitch and heave accelerations were 5.5 degrees/sec^2 and 1.3 G's respectively. At the other headings of beam and quartering waves, pitch and heave accelerations decreased sharply with magnitudes less than 1.7 degrees/sec^2 and 0.3 G's. Roll acceleration was most pronounced in bow waves with the chine flaps attached to the craft. In that case, the measured significant roll acceleration was 3.5 degrees/sec^2. Without chine flaps, roll acceleration diminished to 1.2 degrees/sec^2. The only other roll acceleration of significance with a magnitude of 1.4 degrees/sec^2 occurred in quartering waves for the chine flapped craft. Roll accelerations for the remaining 30 knot craft speed conditions were measured to be less than 0.8 degrees/sec^2.

Craft accelerations at zero speed were minimal for the craft with and without chine flaps. Significant pitch, heave and roll accelerations did not exceed 1.1 degrees/sec^2, 0.2G's and 0.8 degrees/sec^2 respectively with the maximum pitch acceleration occurring in head waves and maximum roll acceleration in beam waves.

The same general trend in accelerations was observed in the Sea State 3 and 4 environments (Figures 3b and 3c) where the craft speeds were 15 and 5 knots respectively. With the progressively reduced craft speed for each successive sea state, accelerations were observed to decline accordingly. Maximum accelerations in Sea State 3 and 4 were observed to occur again with the chine flapped craft in bow waves at the specified forward speeds. Removal of the chine flaps tended to reduce the accelerations. For both craft configurations and at the other headings of 90 and 45 degrees, the planing characteristics of the craft with forward speed tended to reduce accelerations somewhat to levels below the zero speed responses. At zero speed in the three headings of bow, beam and quartering waves, accelerations in pitch, heave and roll increased with sea state as would be expected.

PERFORMANCE IN COASTAL SWELLS

In the 10 second period 4.0 foot high (full scale) swell, the craft's responses at headings of 135, 90 and 45 degrees at speeds of 0 and 30 knots are presented in Table 4 in terms of non-dimensional acceleration transfer functions. Acceleration transfer functions are for pitch, heave, and roll as well as for the vertical accelerations of the craft's bow, CG, and stern in the body reference frame. The transfer function T for the vertical acceleration is expressed as

$$T = \frac{A}{h\omega_e^{\,2}}$$

where A is the response amplitude for the vertical acceleration

$(h\omega_e^{\,2})$ is the excitation amplitude of the wave's vertical acceleration

h is the wave amplitude

ω_e is the encounter frequency.

The angular acceleration transfer function is given as

$$T = \frac{A}{\left(\frac{2\pi h\omega_e^{\,2}}{\lambda}\right)}$$

where A is the response amplitude for the angular acceleration

$\left(\frac{2\pi h\omega_e^{\,2}}{\lambda}\right)$ is the excitation amplitude of the wave slope's rate of change

λ is wave length.

Responses for the craft travelling at 30 knots in quartering waves had to be deleted due to the low wave encounter frequency. With the allowable distance in carriage travel, the excitation and response obtained from the LVA model in one pass constituted less than one cycle. Some discrepancies may be noted in pitch and roll with regard to heading for the craft at zero speed. This was due to the difficulty in maintaining the model at the constant desired heading during the time data was collected.

In general, all craft accelerations in the long wave period of 10 seconds were minimal with the craft merely contouring the wave. Vertical craft accelerations, as can be seen from their transfer functions, were nearly equal to the wave's vertical acceleration. Of the swell conditions investigated, the 30 knot bow waves case had both the highest encounter frequency of 1.07 rad/sec (full scale) and the highest vertical craft accelerations. All three locations of bow, CG, and stern experienced accelerations less than 0.07 G's. The influence of chine flaps on LVA responses to swells was minimal. At 30 knots, the chine flaps tended to increase craft responses somewhat in the headings of 135 and 90 degrees whereas at zero speed they tended to damp the responses. The latter is particularly evident in quartering waves where the chine flaps reduced craft motions by nearly 25 percent.

HABITABILITY ESTIMATES IN A SEAWAY

In addition to a discussion of LVA responses in coastal wave environments, it is important to compare the measured wave induced craft accelerations with acceleration exposure criteria for shipboard personnel. The criteria, as provided by the sponsor,

is the MIL-STD-1472A of May 15, 1970, extrapolated to frequencies less than 1 Hz. The criterion curve shown in Figures 4a thru 4g and 5a thru 5g imposes the maximum allowable exposure to vertical accelerations for personnel to maintain proficiency for a period of one hour. The accelerations of substantial magnitude in irregular waves at 180, 135 and 90 degree headings occurred at the bow in particular and at the CG. Stern accelerations were relatively small with narrowband acceleration intensities less than the one-hour exposure criterion. Consequently, the figures present only the vertical acceleration intensities of the bow and CG for both the irregular wave and swell conditions in the three headings. In quartering waves all craft vertical accelerations were minimal due to the low wave encounter frequencies. The one-hour acceleration criterion for this heading is therefore easily satisfied.

Impact accelerations as shown in the time history of the 30 knot, head Sea State 2 case with no chine flaps (Figure 6) indicate magnitudes in the order of 6 G's with a duration of approximately 0.11 seconds (full scale). Such accelerations are partly governed by the model's rigidity. The short duration as well as the relatively infrequent occurrence of impacting make their contribution to overall craft motions insignificant, as pointed out earlier although they may adversely affect habitability.

From Figures 5a through 5g, the craft without chine flaps is generally more habitable than the craft with chine flaps. Furthermore, relative comfort increases in going from the bow to the stern for both craft configurations. The severest vertical accelerations occurred at the craft's bow in head and bow waves at forward speed. In head Sea State 2 at 30 knots (Figure 4a) the bow of the chine flapped craft exceeded the one-hour acceleration criterion by about 50 percent whereas the no chine flapped craft was on the criterion curve.

For the same two cases the vertical CG acceleration of only the chine flapped craft slightly exceeded the acceleration criterion. In bow seas acceleration levels consistantly exceeded criterion limits when speed was reduced with increasing sea states (Figures 4b thru 4d). Both bow and CG accelerations in the 10 second period, 4.0 foot high swell with a craft speed of 30 knots and 135 degree heading (Figure 4b) were approximately equal to the allowable limits of the MIL specification. In beam seas, namely Sea State 2 and a 10 second period swell, Sea State 3 and 4 at the corresponding speeds of 30, 15 and 5 knots, bow and CG accelerations were well below the maximum acceptable acceleration levels (Figure 4e - 4g).

With the LVA at zero speed, Figures 5a thru 5g generally show the chine flaps to be negligible in altering the craft's response. Bow acceleration levels again exceed the levels experimenced at the CG although both are generally less than the allowable limits imposed by the criterion. The only exception occurs for the bow acceleration in Sea State 3 and 4 at 135 degree heading and Sea State 4 at 90 degree heading. In these cases, acceleration levels in the 0.25 Hz center freqency band exceeded the criterion's limit by 25%. Craft responses to swell conditions at zero speed are all acceptable.

With the manual steering of the LVA model, controllability was, of course, a function of the operator's skill. Given in Figure 7 is an example of rudder displacement on the model in bow seas for the chine flapped LVA. Although time and speed have been Froude scaled, caution should be exercised in quantitatively relating the rudder displacement to full scale, due both to rudder scaling problems in general and to an improperly scaled rudder on the model in particular. Even so, general trends observed with rudder displacement on the model are still valid for the full scale LVA.

Heading could be maintained with ease especially at the design speed of 30 knots. Sometimes rudder angle could even be kept constant throughout an experimental pass in bow and beam waves. At low speeds and in stern quartering seas, where the water velocity past the rudder is reduced, rudder effectiveness is reduced and steering became more difficult, yet still quite manageable, as Figure 7 shows. Considering the comparable response time on the full scale craft to be 3.5 times that for model scale, no exceptional demands on the operator are foreseen in manually steering the LVA.

CONCLUSIONS

Seakeeping characteristics of a 1/12 scaled model planing hull of a 55,000 lb. LVA concept, together with the effects of optional chine flaps, were experimentally investigated using optimum calm water ballast conditions and trim tab settings. Based on an analysis of experimental results, the following conclusions were made concerning the LVA's motion responses to Sea States 2, 3, 4, and 10 second full-scale period swell conditions at various craft speeds and headings of 180, 135, 90, and 45 degrees.

AT FORWARD SPEED

1. The effect of chine flaps generally increased LVA responses to a given wave condition, heading, and speed.
2. The highest accelerations experienced, particularly at the LVA's bow, were in head and bow waves while advancing at 30 knots in a Sea State 2 and swell. Both bow and CG accelerations exceeded somewhat the one-hour acceleration criterion in which proficiency can be maintained as defined by MIL specifications.

3. Reducing speed with increasing sea states in bow waves, namely 15 knots in a S.S.3 and 5 knots in a S.S.4, reduced peak accelerations. Yet the peaks still exceeded acceptable levels due to a shift towards lower frequencies.

4. In beam and quartering waves for the same wave conditions and craft speeds, all craft accelerations were within acceptable levels.

5. Impacting occurred in head and bow waves at the high speed of 30 knots in Sea State 2 and became less frequent at the reduced speeds in the higher Sea State of 3 and 4.

6. Manually steering the full-scale LVA at a given heading in waves should require no exceptional skills on the part of the operator. The worst condition is in quartering waves where rudder effectiveness sharply declines. But even there, steering is quite manageable.

AT ZERO SPEED

1. The presence of chine flaps had no noticeable effect in altering LVA's responses to a given wave condition and heading.

2. Craft vertical accelerations were generally minimal and within the acceptable acceleration limits. The only slight exception was bow acceleration at the higher Sea States of 3 and 4 at 135 degree heading and Sea State 4 at 90 degree heading. Acceleration levels in these instances exceeded acceptable limits by less than 25% in the 0.25 Hz center frequency band.

3. No impacts occurred in the zero speed test matrix, namely head Sea State 2 and bow, beam, and quartering Sea State 2, 3, 4, and the 10 second period swell.

ACKNOWLEDGMENTS

The author wishes to thank Messrs. G. Minard for operating all of the electronic instrumentation and J. A. Bonilla-Norat for assistance in conducting the model experiments. Further thanks are extended to Messrs, J. B. Peters and M. Davis for carrying out all computer data reduction and to E. Zarnick for invaluable contributions in all aspects of this study.

REFERENCES

1. Savitsky, D., Numata, E., and Chiocco, M., "Preliminary Hydrodynamic Model Tests of Several LVA Planing Hull Concepts", Stevens Institute of Technology Report DL-75-1840 (October 1975).

TABLE 1

LVA PARTICULARS
(FULL SCALE)

	METRIC	ENGLISH
WEIGHT	25.0 m-tons	55,000 Lbs. (24.6 L-Tons)
LOA	9.18 m	30.1 ft.
BEAM	3.35 m	11.0 ft.
HULL DEPTH	2.29 m	7.5 ft.
DRAFT	.94 m	3.1 ft.
VCG above baseline	1.07 m	3.5 ft.
LCG forward of transom stern	3.66 m	12.0 ft.
ADJUSTABLE TRANSOM STERN FLAP		
CHORD	.79 m	2.6 ft.
SPAN	3.35 m	11.0 ft.
OPTIONAL CHINE FLAP		
CHORD	4.60 m	15.1 ft.
SPAN	.76 m	2.5 ft.
MID-CHORD FWD OF MIDSHIP	0	0
GYRADII		
PITCH (k_θ/LOA)	0.27	
YAW (k_ψ/LOA)	0.26	
ROLL (k_ϕ/BEAM)	0.26	
STATIC TRIM ANGLE	4.9 deg. BOW UP	

TABLE 2 - LVA IRREGULAR WAVE EXPERIMENT MATRIX

CRAFT HEADING	CRAFT SPEED (KNOTS)	SEA STATE	NO CHINE FLAPS	WITH CHINE FLAPS
Head Sea (180°)	0	2	x	x
	30	2	x	x
Bow Sea (135°)	0	2	x	x
	30	2	x	x
	0	3	x	x
	15	3	x	x
	0	4	x	x
	5	4	x	x
Beam Sea (90°)	0	2	x	x
	30	2	x	x
	0	3	x	x
	15	3	x	x
	0	4	x	x
	5	4	x	x
Stern Quartering Sea (45°)	0	2	x	x
	30	2	x	x
	0	3	x	x
	15	3	x	x
	0	4	x	x
	5	4	x	x

TABLE 3 - LVA 10-SECOND PERIOD SWELL (REGULAR WAVE)

EXPERIMENT MATRIX

CRAFT HEADING	CRAFT SPEED (KNOTS)	NO CHINE FLAPS	WITH CHINE FLAPS
Bow Sea (135°)	0 30	x x	x x
Beam Sea (90°)	0 30	x x	x x
Stern Quartering Sea (45°)	0 30	x x	x x

TABLE 4

LVA MOTION RESPONSES TO COASTAL SWELLS (10 SECOND PERIOD, 1.4 DEGREE WAVE SLOPE) AT VARIOUS CRAFT SPEEDS AND HEADINGS

Config.	Head (Deg)	Speed (Knots)	Transfer Functions				
			Accelerations		Vertical Accelerations		
			Pitch	Roll	Bow	CG	Stern
No Chine Flaps	135	0	.0210	.0245	1.01	1.02	1.04
		30	.0295	.0229	.95	.99	1.03
	90	0	.0053	.0376	1.00	1.03	1.05
		30	.0045	.0436	1.09	1.10	1.13
	45	0	.0266	.0229	1.12	1.09	1.10
With Chine Flaps	135	0	.0181	.0275	1.01	1.02	1.04
		30	.0244	.0201	1.05	1.04	1.07
	90	0	.0133	.0416	1.01	.97	.97
		30	.0078	.0510	1.07	1.10	1.14
	45	0	.0189	.0203	.82	.82	.83

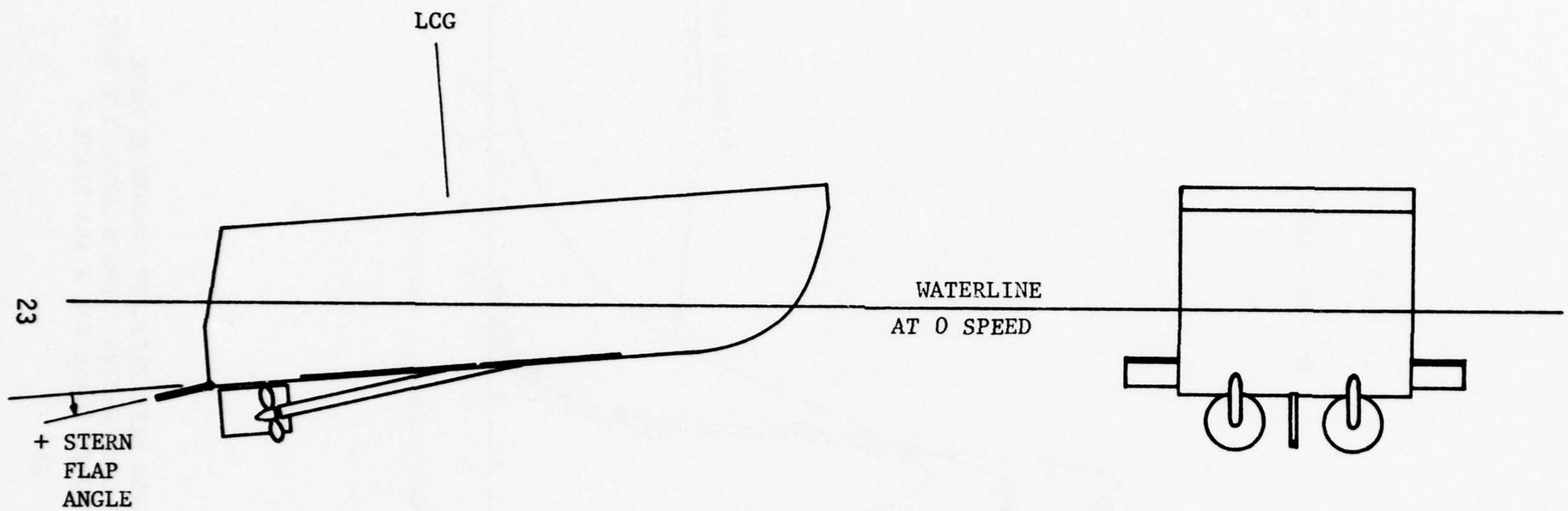


FIGURE 1 - LVA HULL WITH OPTIONAL CHINE FLAPS

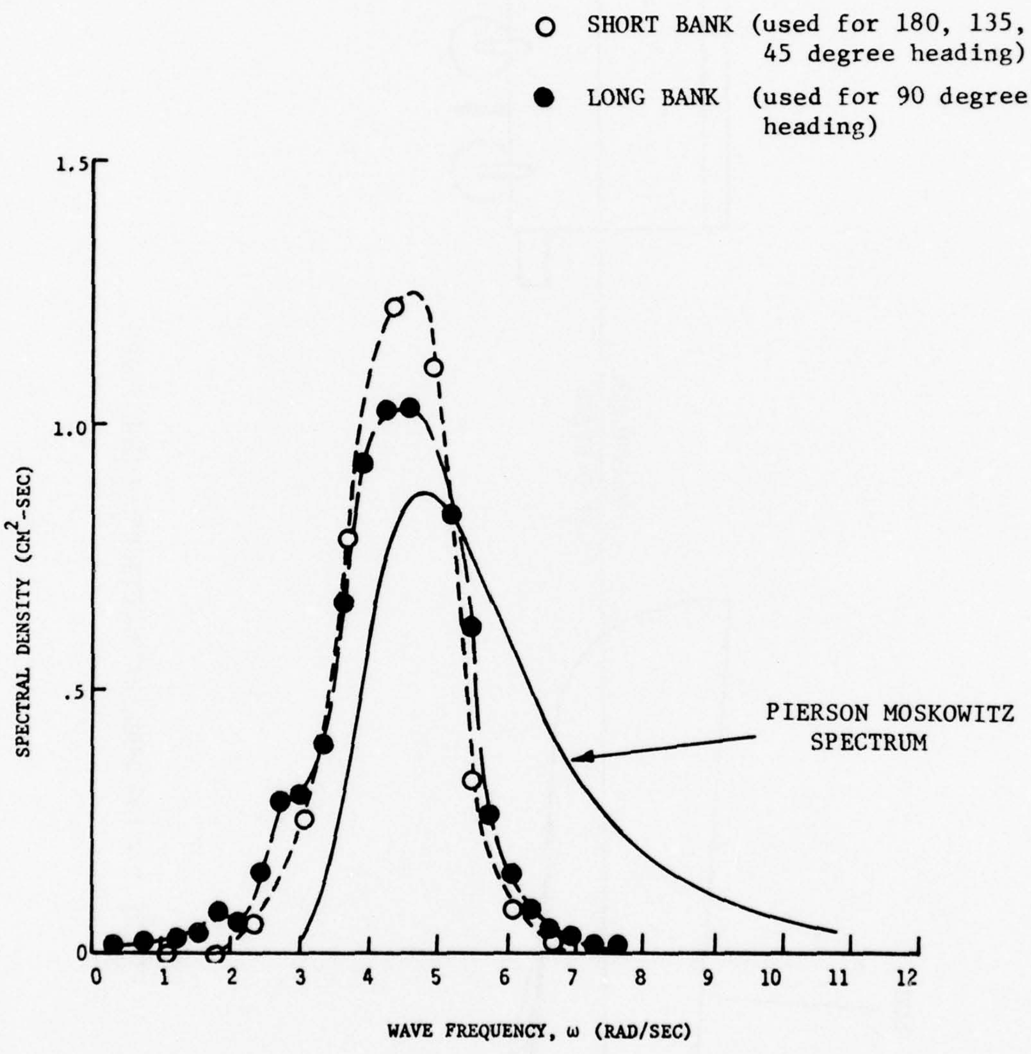


FIGURE 2a - TYPICAL DTNSRDC MASK FACILITY IRREGULAR WAVE SPECTRA WITH COMPARATIVE PIERSON MOSKOWITZ WAVE SPECTRUM AT MODEL SCALE FOR A SEA STATE 2

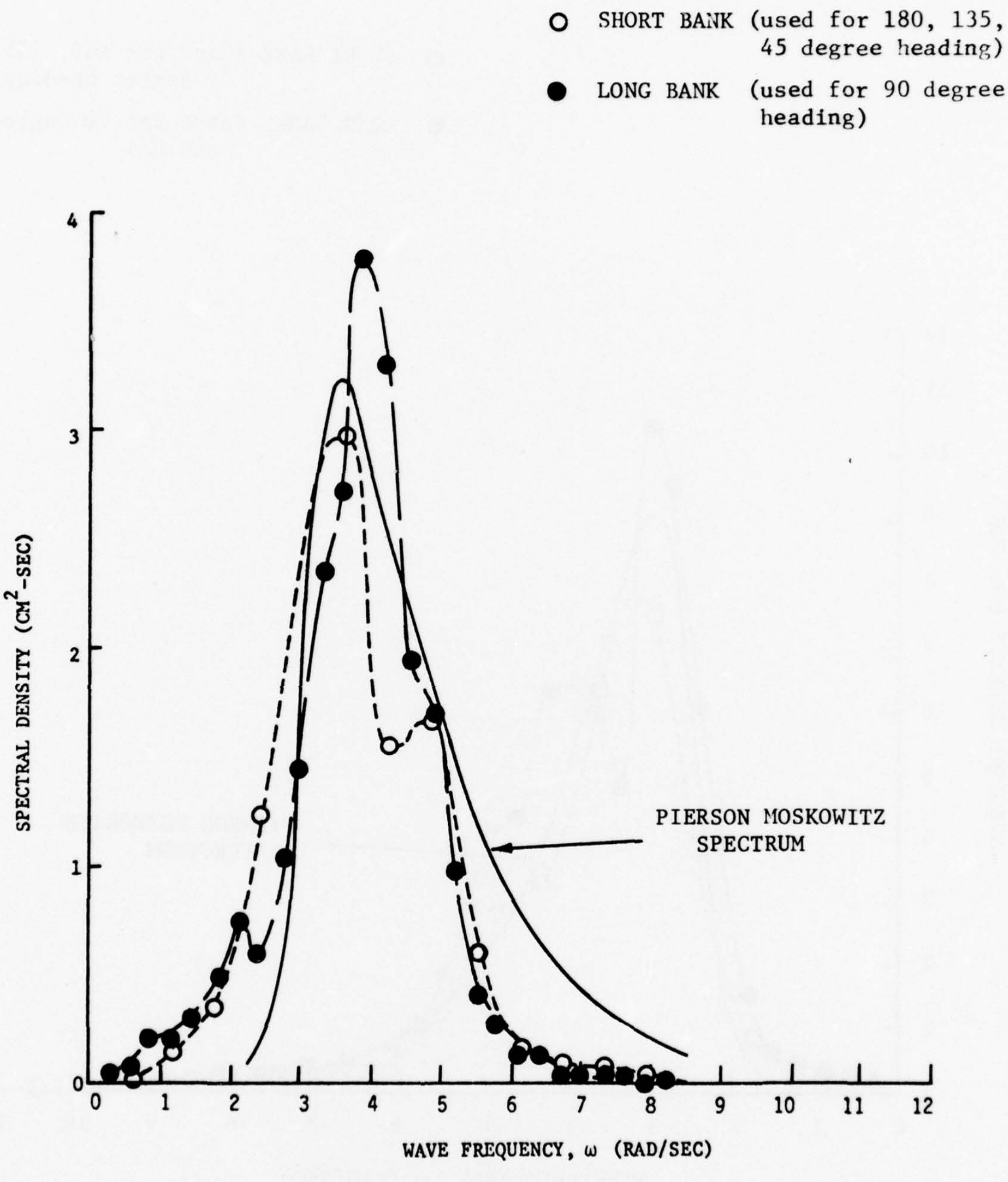


FIGURE 2b - TYPICAL DTNSRDC MASK FACILITY IRREGULAR WAVE SPECTRA WITH COMPARATIVE PIERSON MOSKOWITZ WAVE SPECTRUM AT MODEL SCALE FOR A SEA STATE 3

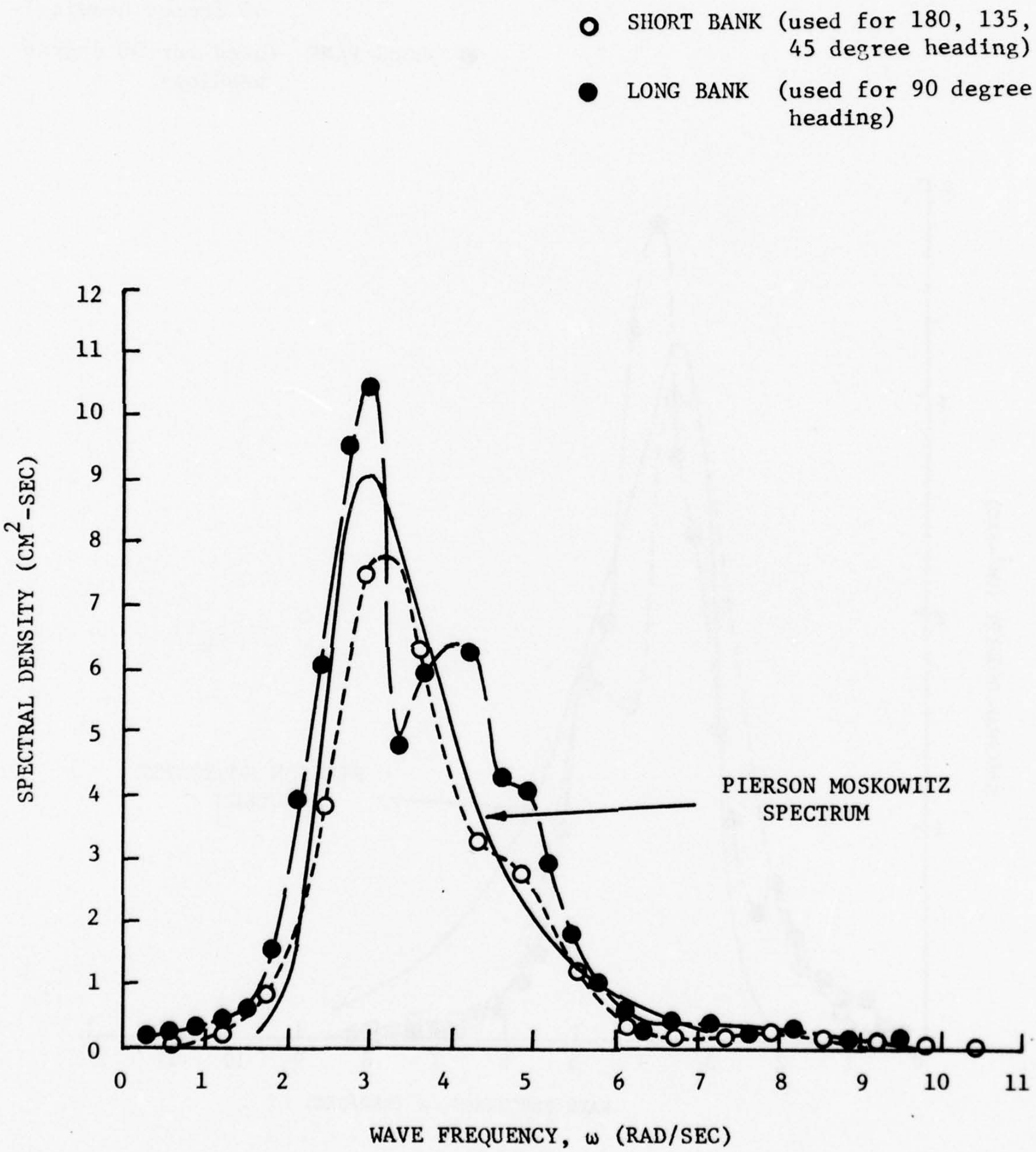


FIGURE 2c - TYPICAL DTNSRDC MASK FACILITY IRREGULAR WAVE SPECTRA WITH COMPARATIVE PIERSON MOSKOWITZ WAVE SPECTRUM AT MODEL SCALE FOR A SEA STATE 4

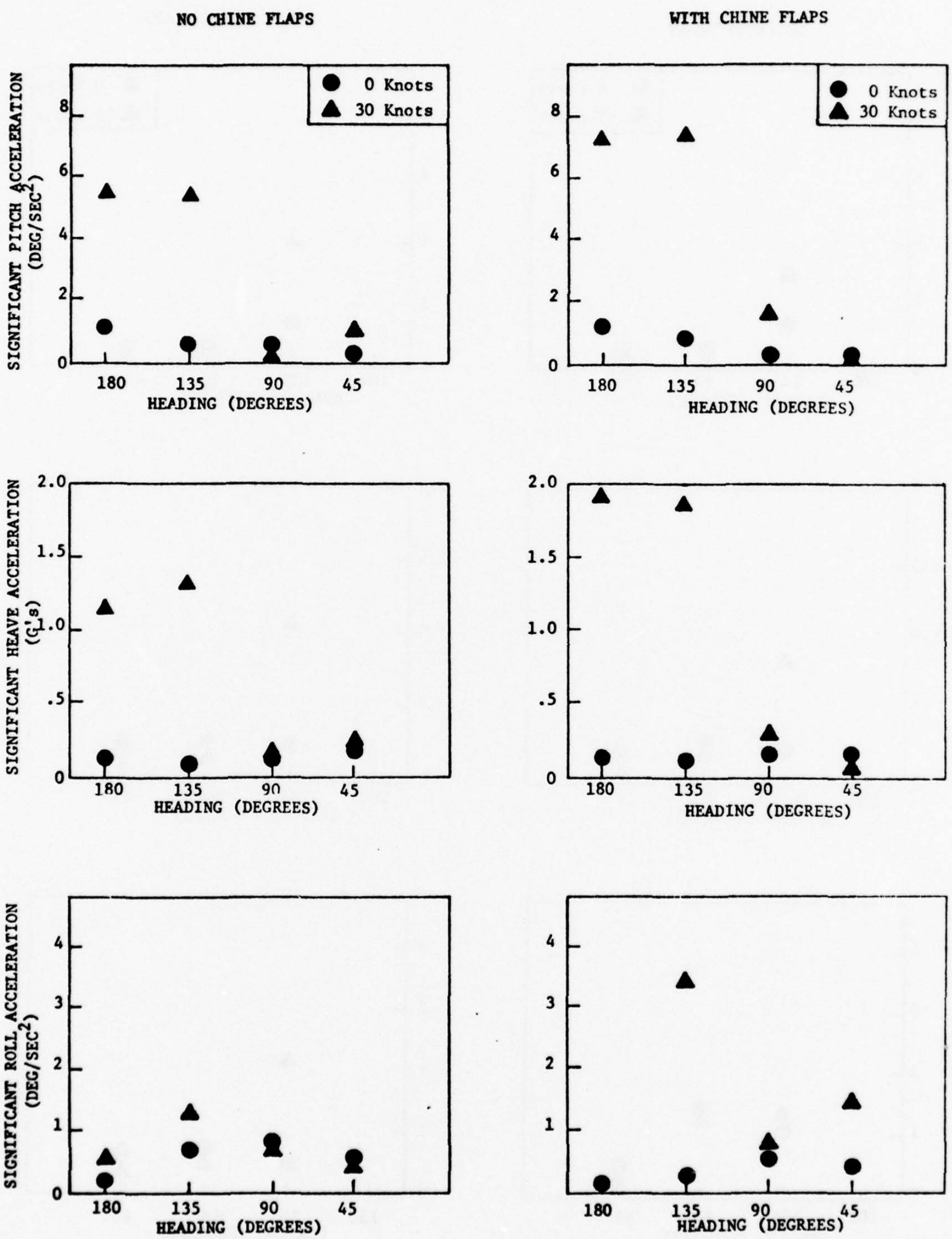


FIGURE 3a - SIGNIFICANT PITCH, HEAVE, AND ROLL ACCELERATION VERSUS CRAFT HEADING FOR THE TWO CONFIGURATIONS OF WITHOUT AND WITH CHINE FLAPS IN A SEA STATE 2

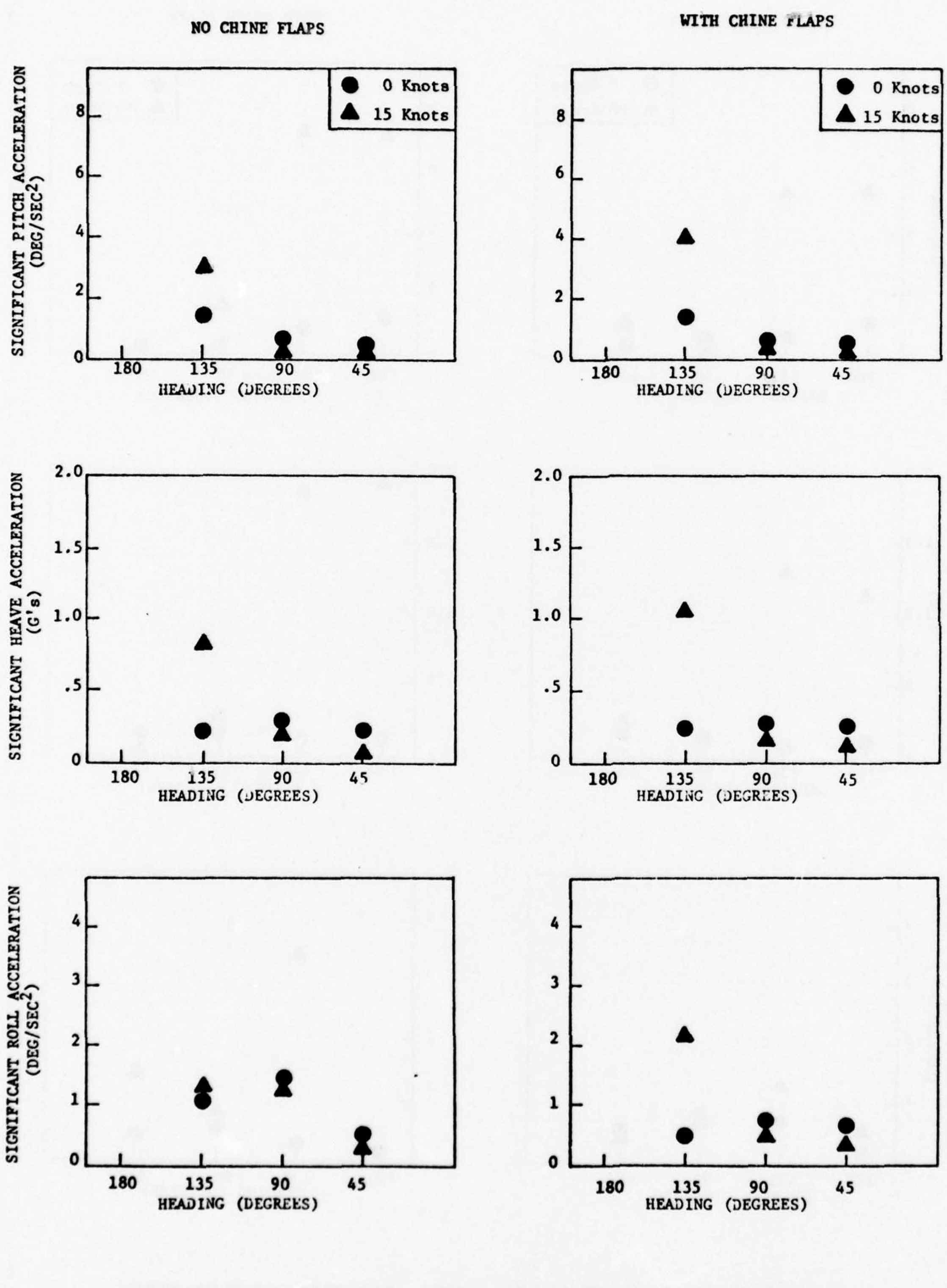


FIGURE 3b - SIGNIFICANT PITCH, HEAVE, AND ROLL ACCELERATION VERSUS CRAFT HEADING FOR THE TWO CONFIGURATIONS OF WITHOUT AND WITH CHINE FLAPS IN A SEA STATE 3

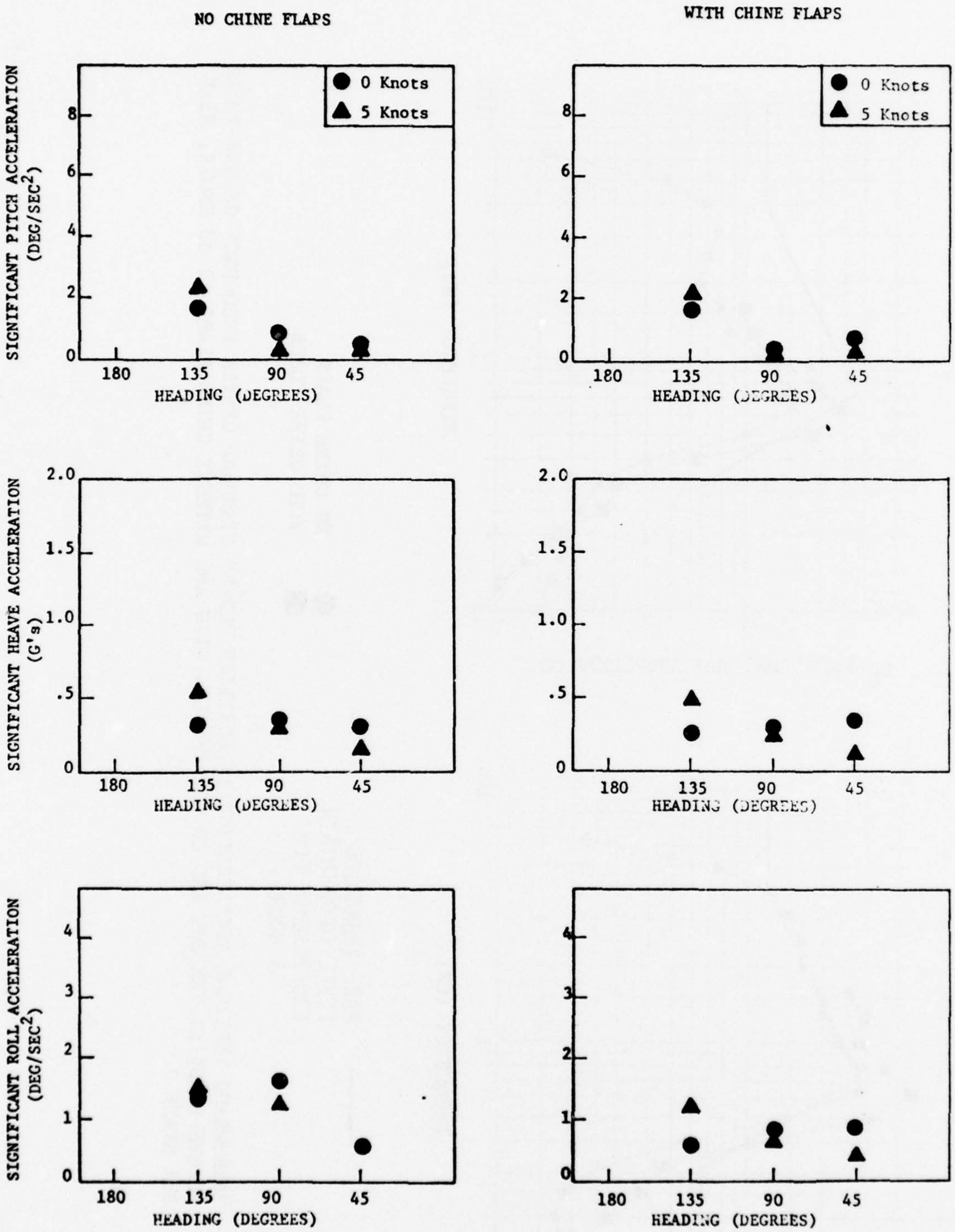


FIGURE 3c - SIGNIFICANT PITCH, HEAVE, AND ROLL ACCELERATION VERSUS CRAFT HEADING FOR THE TWO CONFIGURATIONS OF WITHOUT AND WITH CHINE FLAPS IN A SEA STATE 4

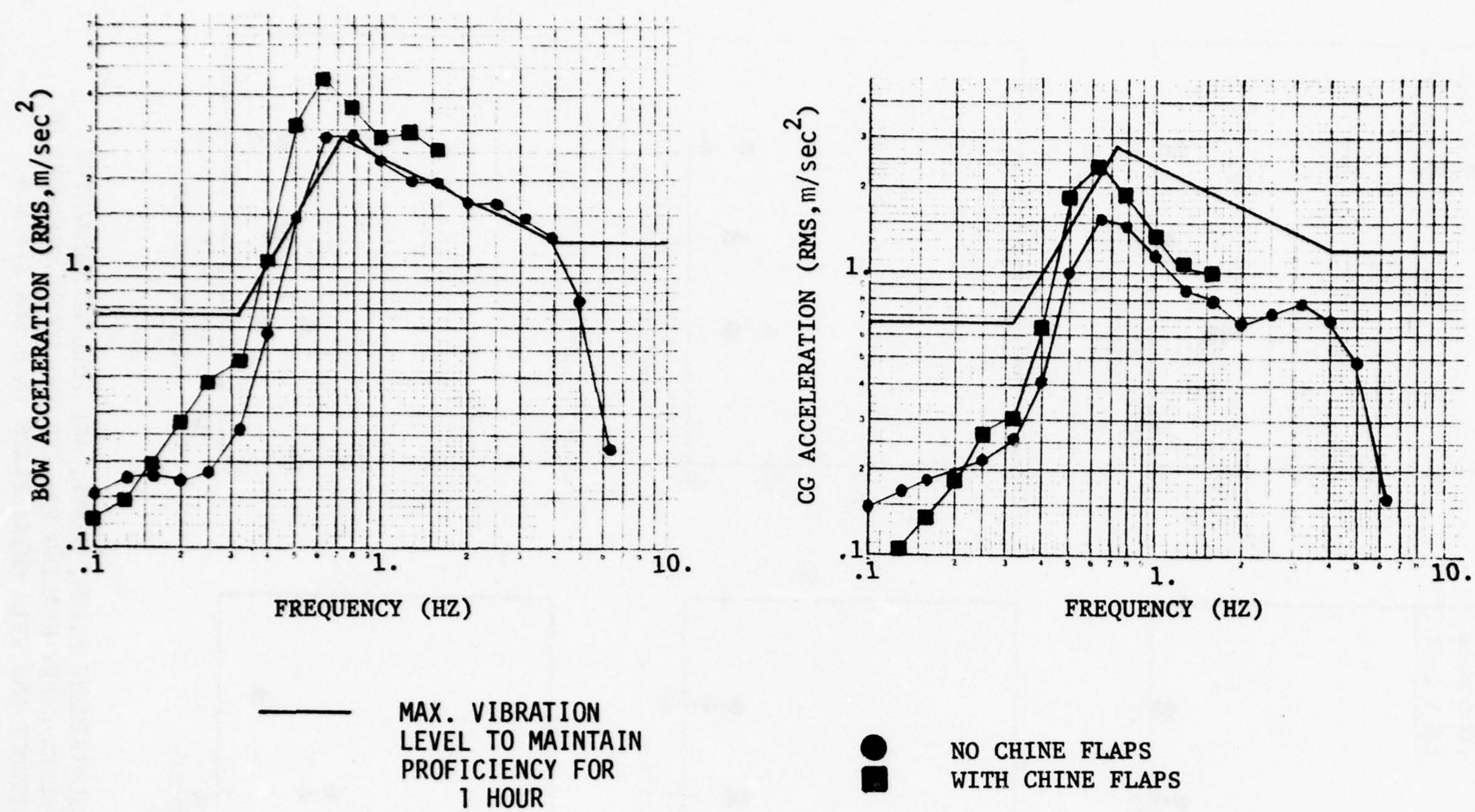


FIGURE 4a - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 30 KNOTS, HEAD SEA STATE 2

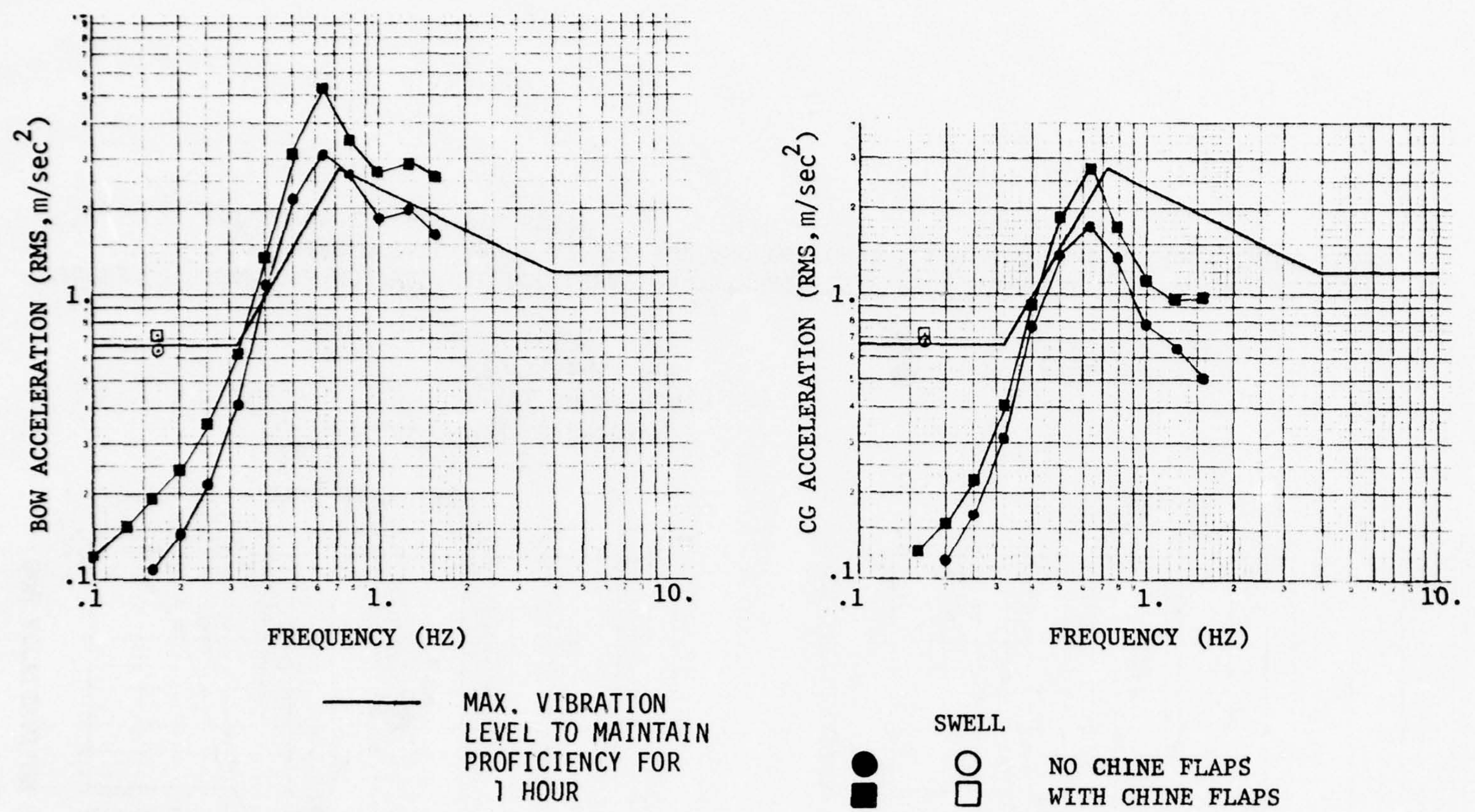


FIGURE 4b - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 30 KNOTS, BOW SEA STATE 2 AND SWELL

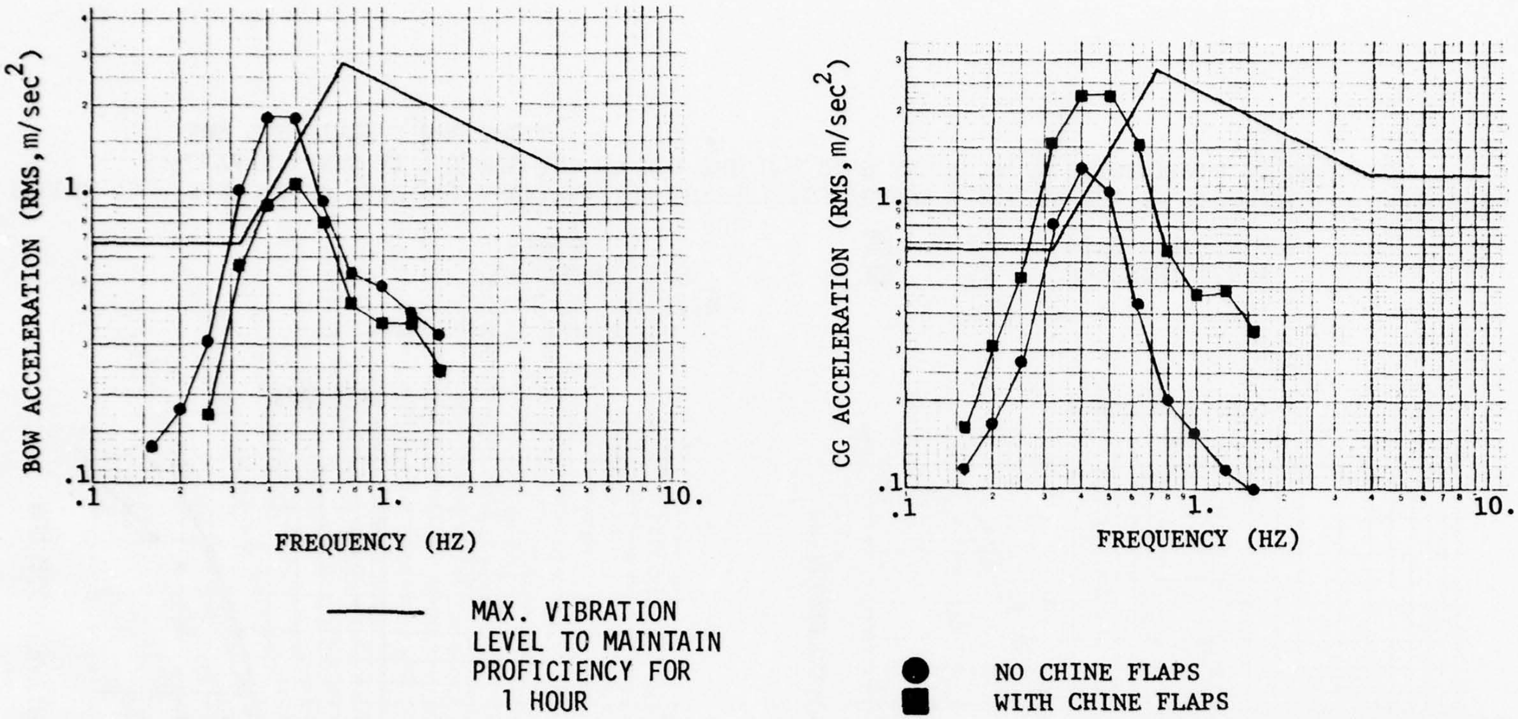


FIGURE 4c - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 15 KNOTS, BOW SEA STATE 3

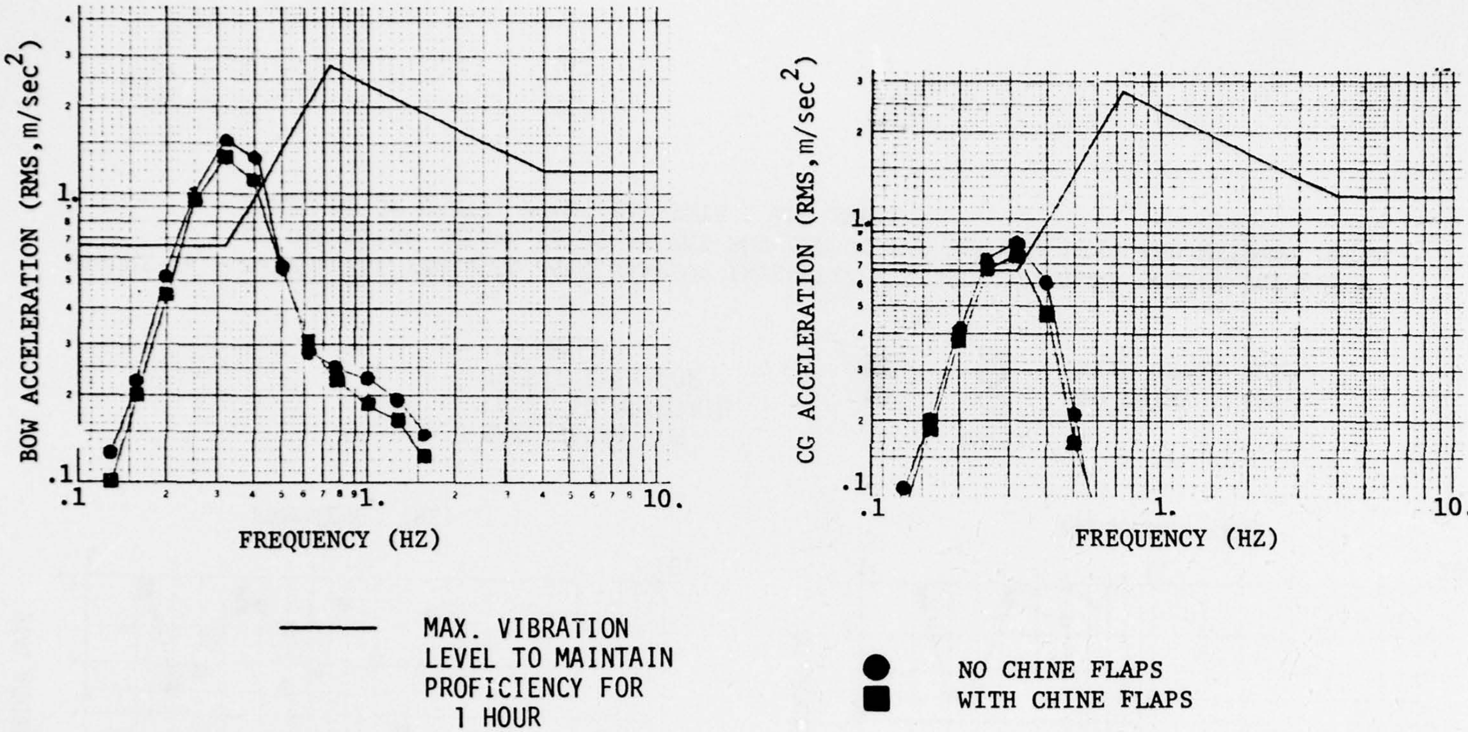


FIGURE 4d - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 5 KNOTS, BOW SEA STATE 4

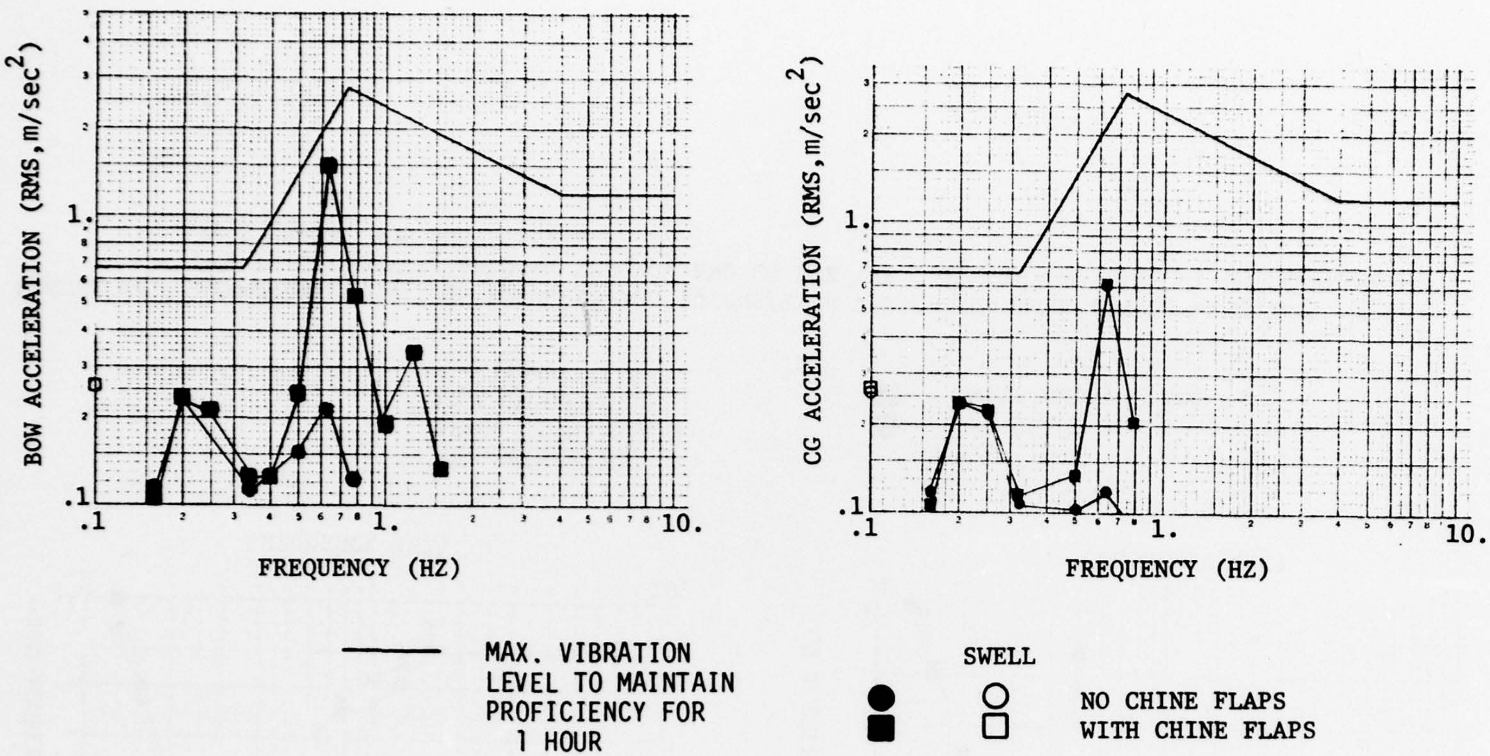


FIGURE 4e - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 30 KNOTS, BEAM SEA STATE 2 AND SWELL

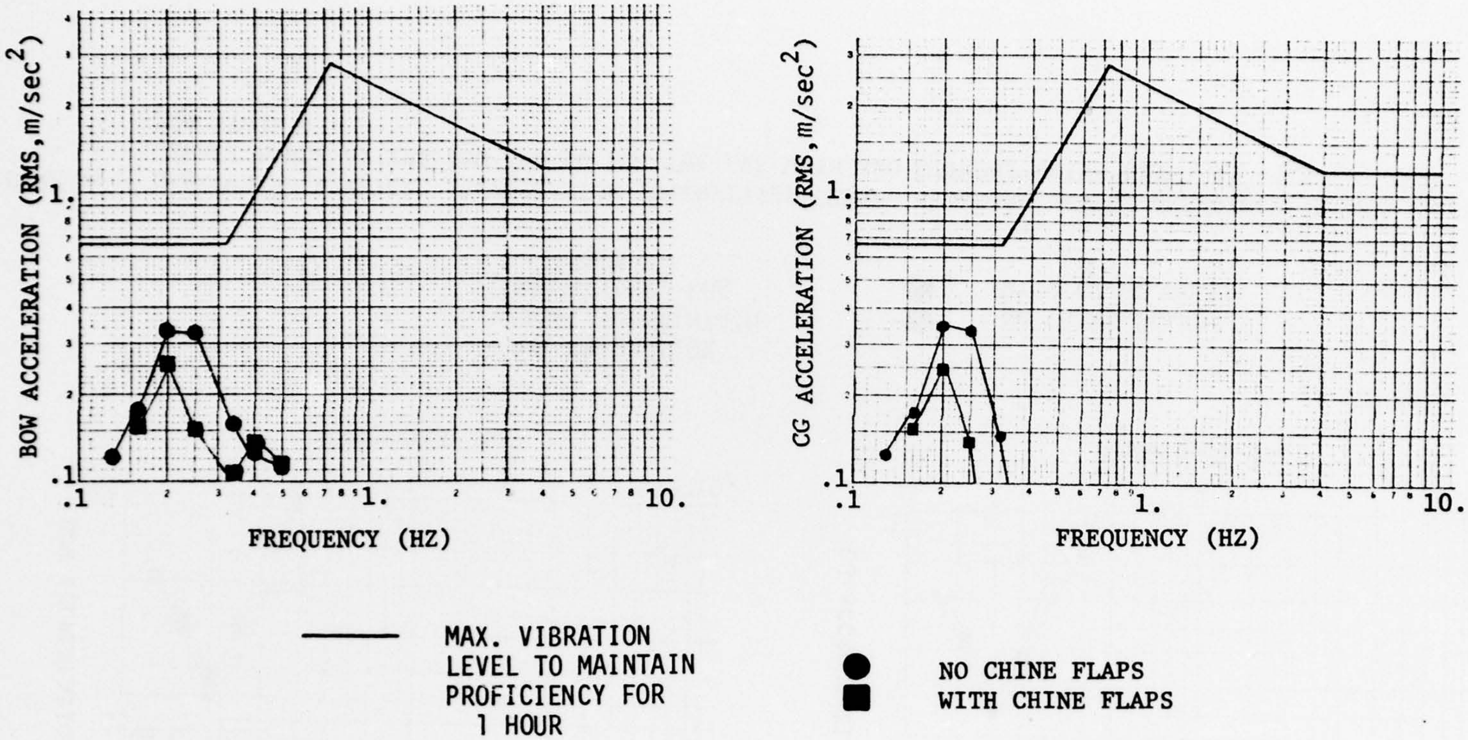


FIGURE 4f - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 15 KNOTS, BEAM SEA STATE 3

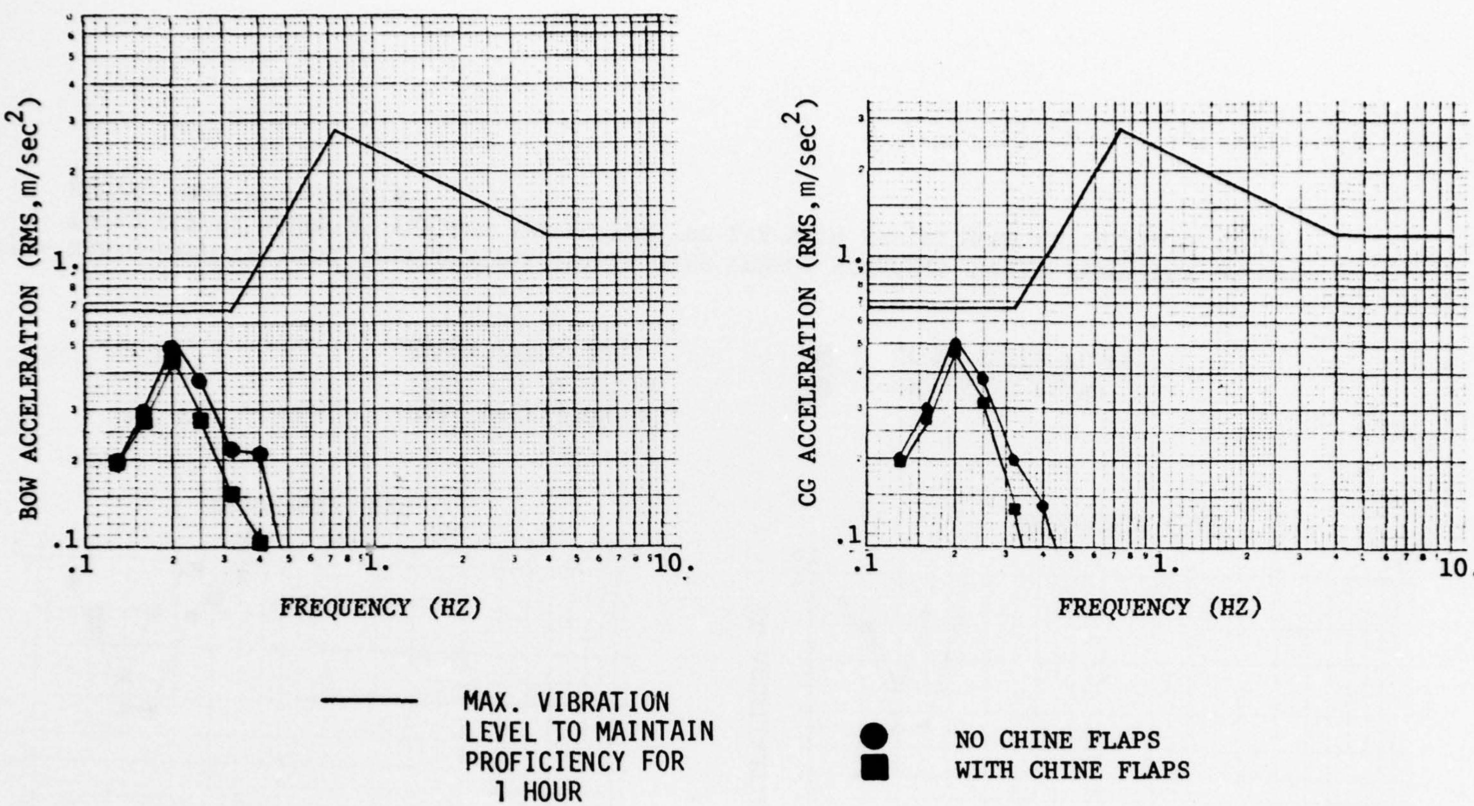


FIGURE 4g - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 5 KNOTS, BEAM SEA STATE 4

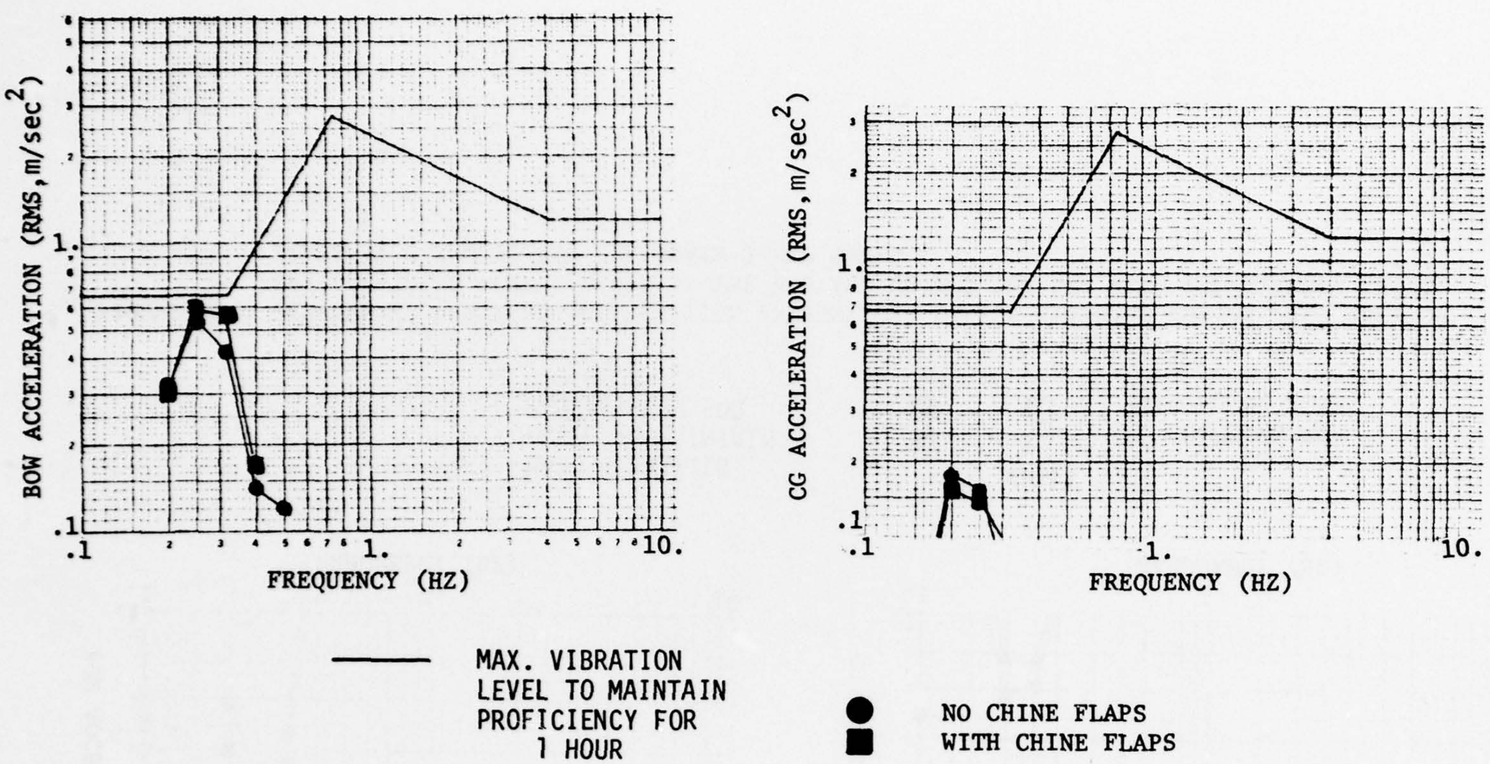


FIGURE 5a - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF THE ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 0 KNOTS, HEAD SEA STATE 2

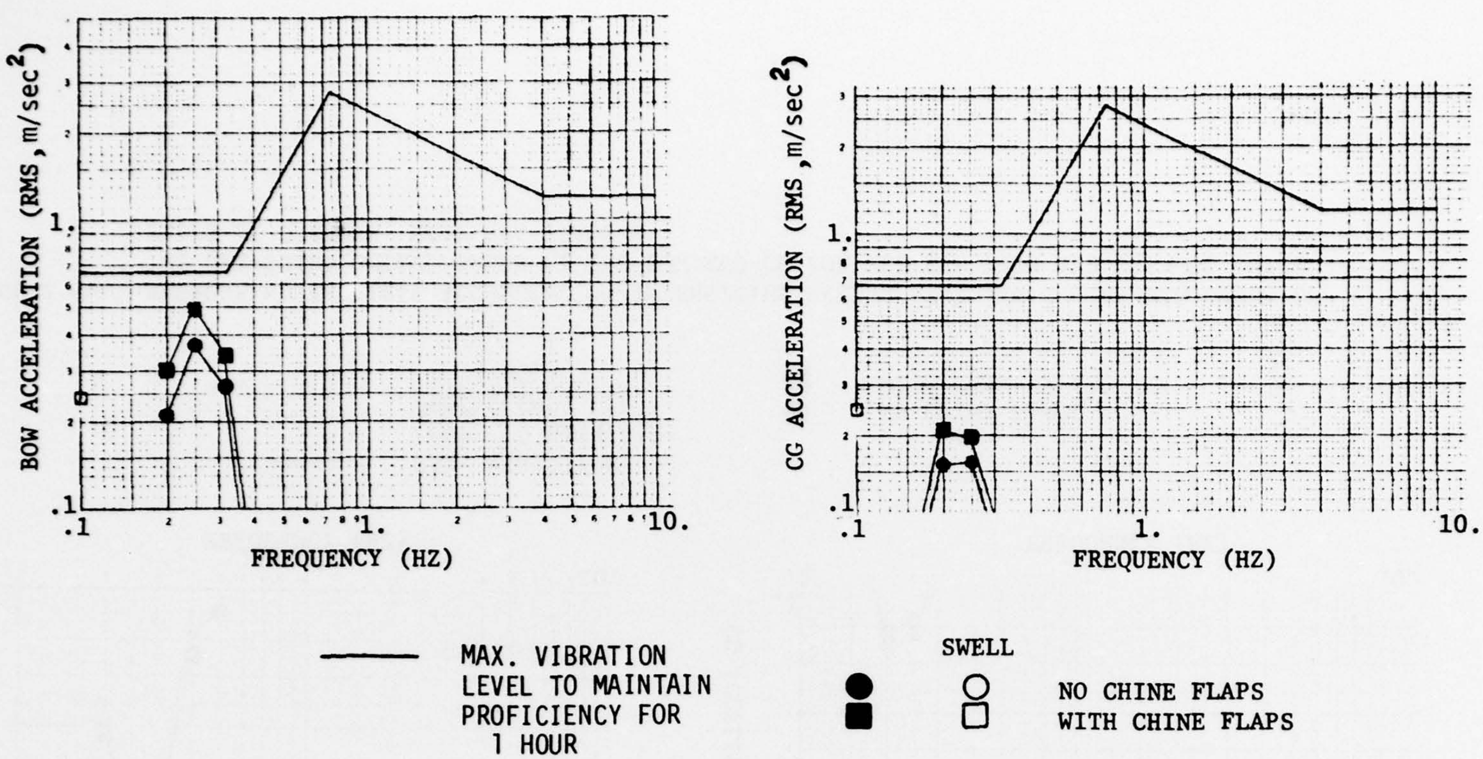


FIGURE 5b - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF THE ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 0 KNOTS, BOW SEA STATE 2 AND SWELL

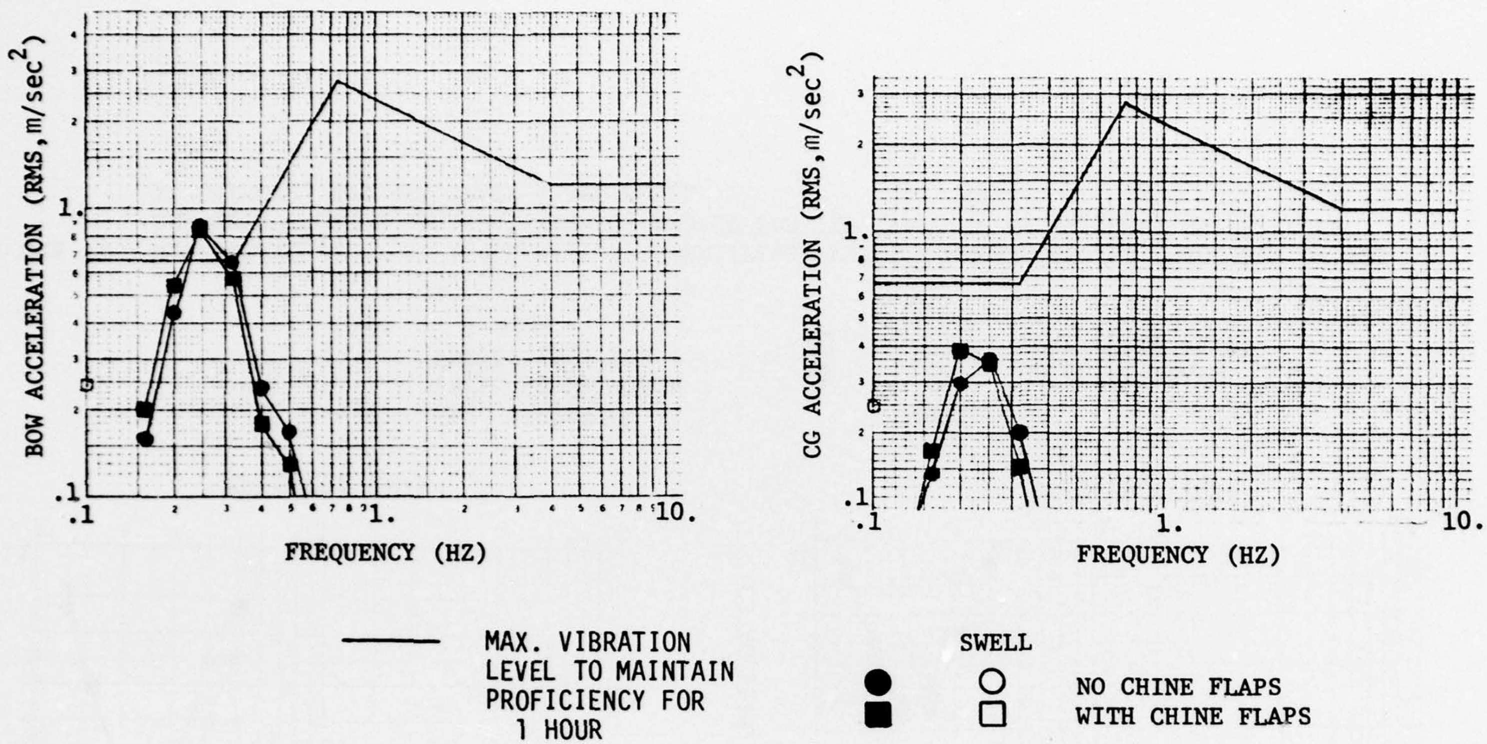


FIGURE 5c - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF THE ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 0 KNOTS, BOW SEA STATE 3 AND SWELL

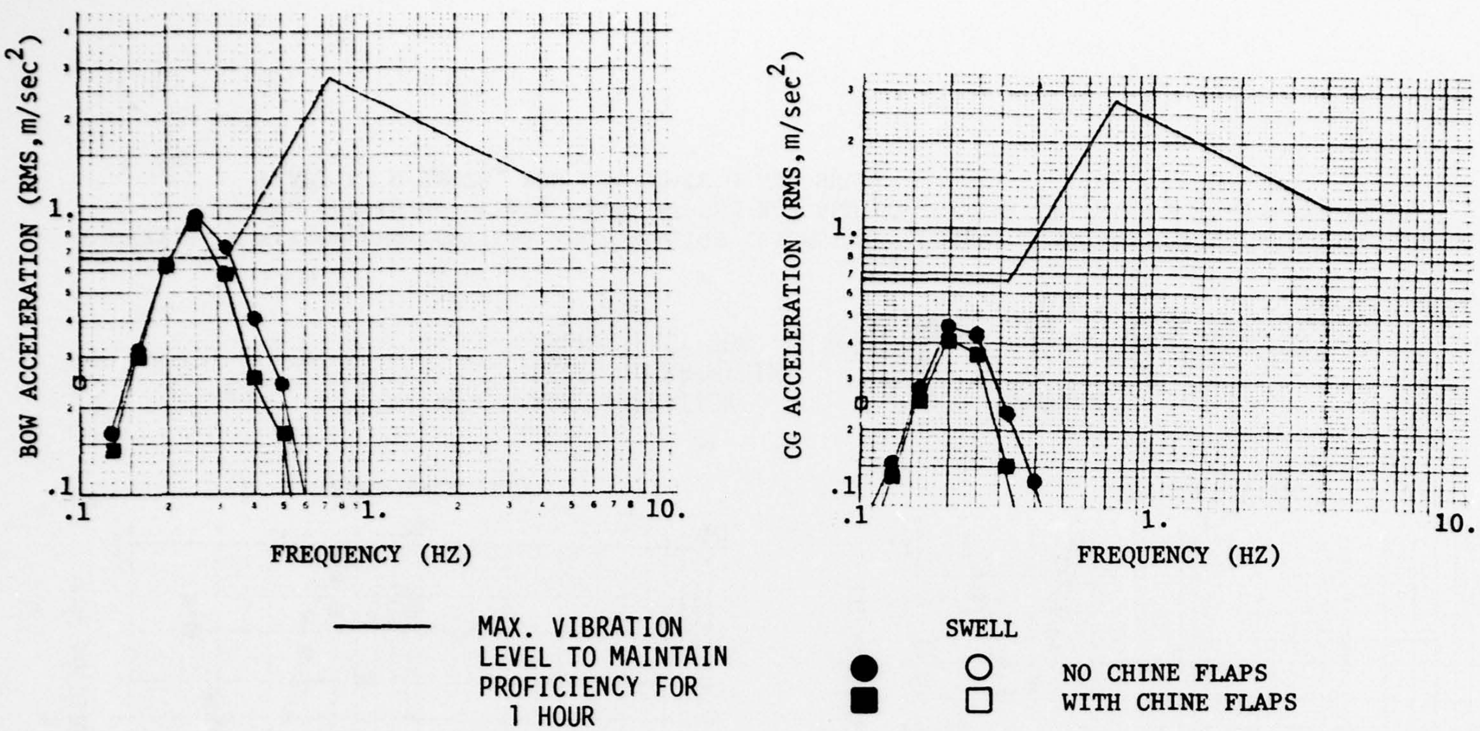


FIGURE 5d - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF THE ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 0 KNOTS, BOW SEA STATE 4 AND SWELL

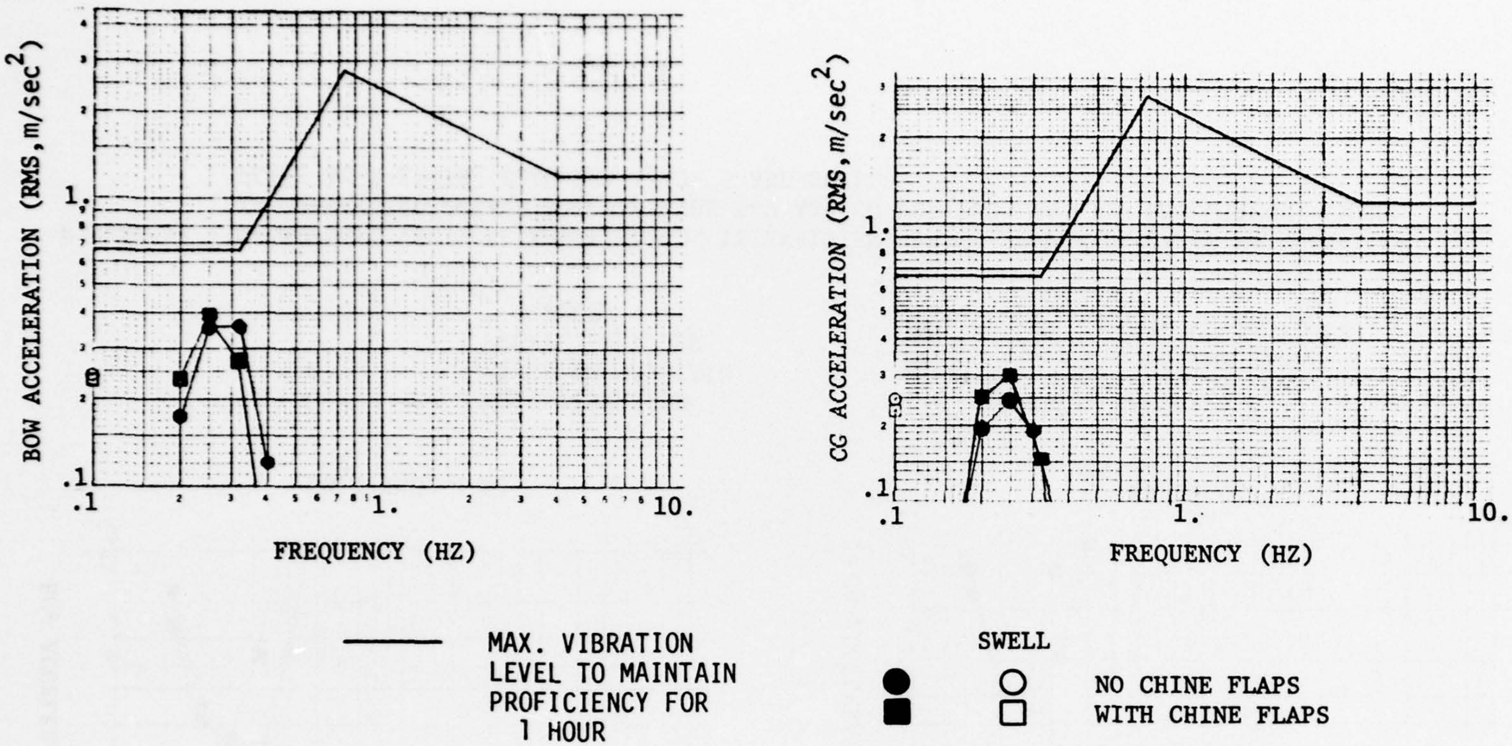


FIGURE 5e - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF THE ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 0 KNOTS, BEAM SEA STATE 2 AND SWELL

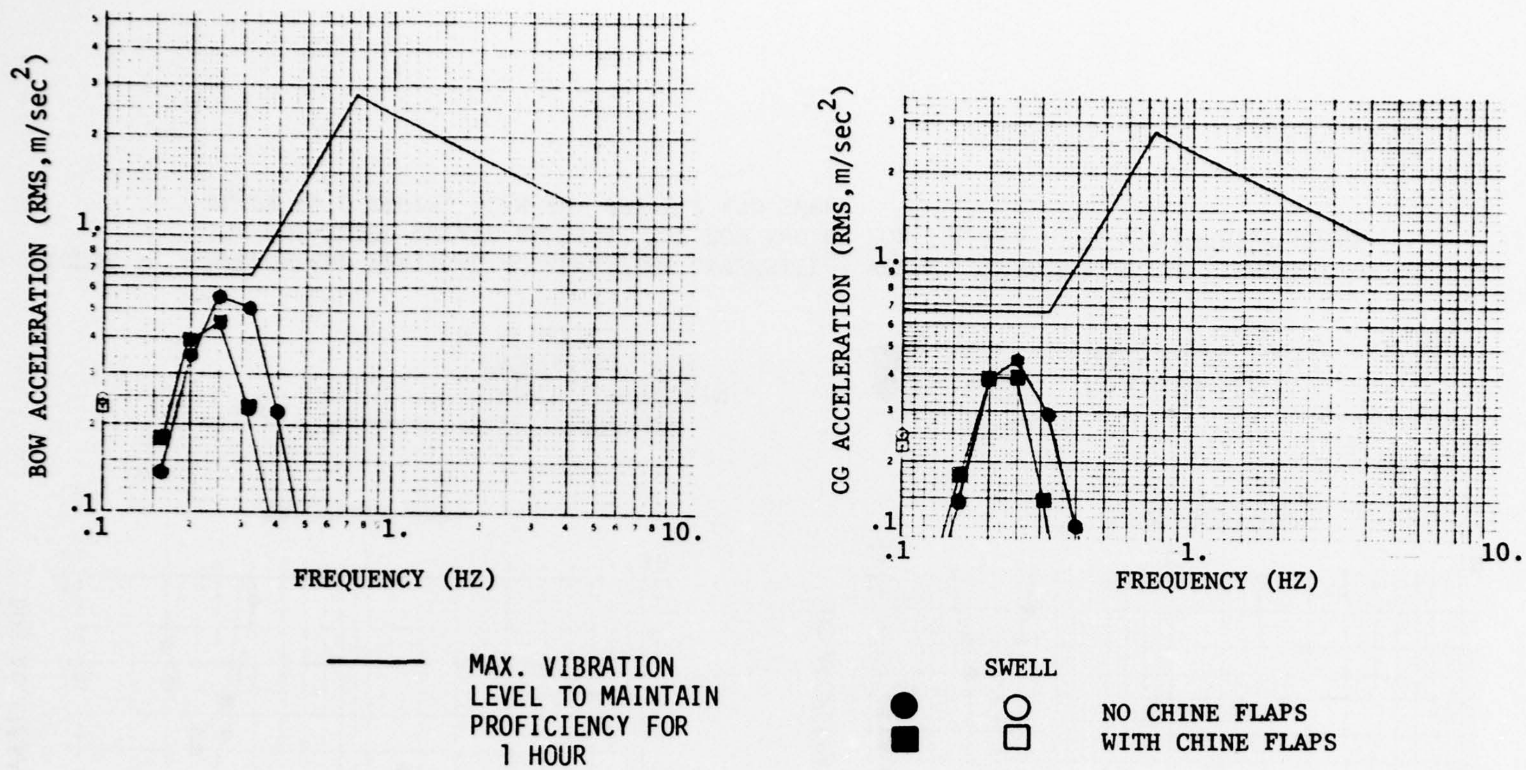


FIGURE 5f - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF THE ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 0 KNOTS, BEAM SEA STATE 3 AND SWELL

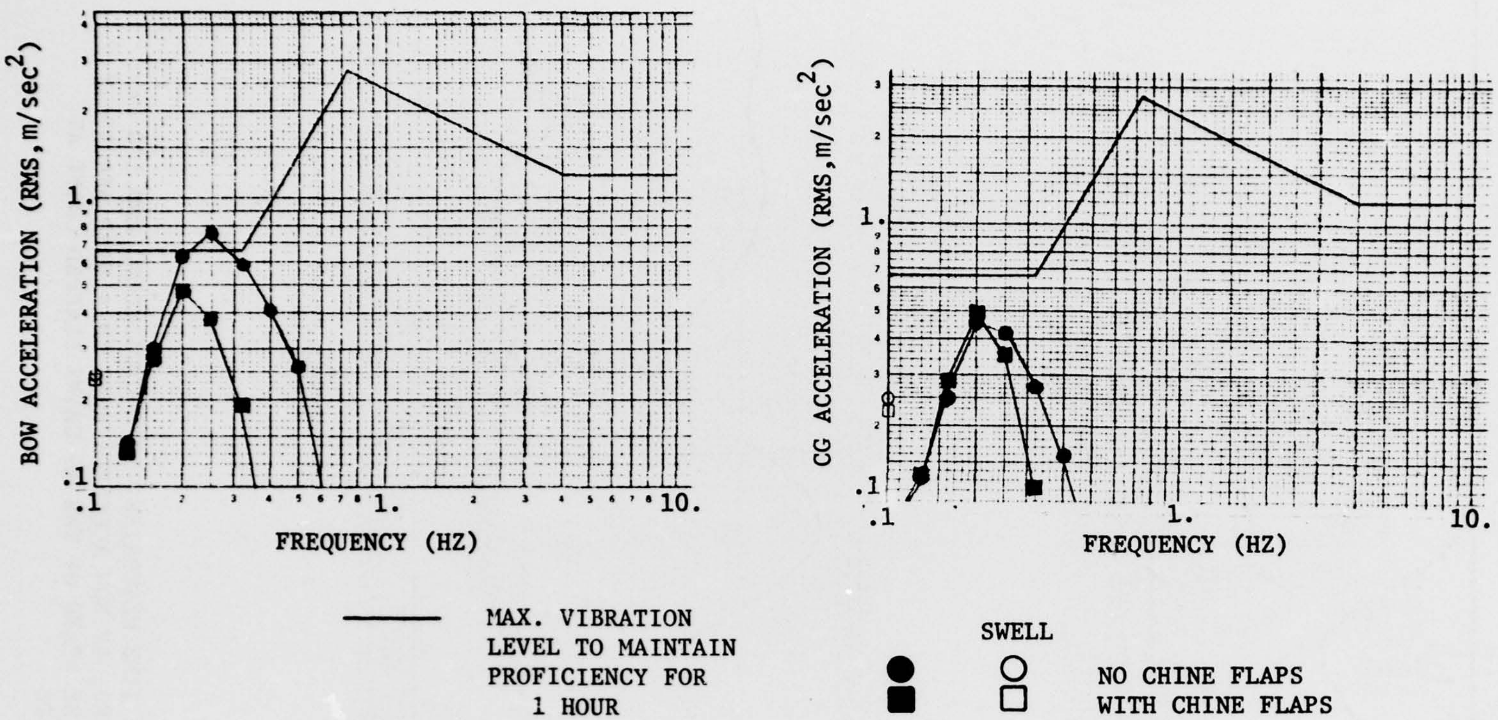
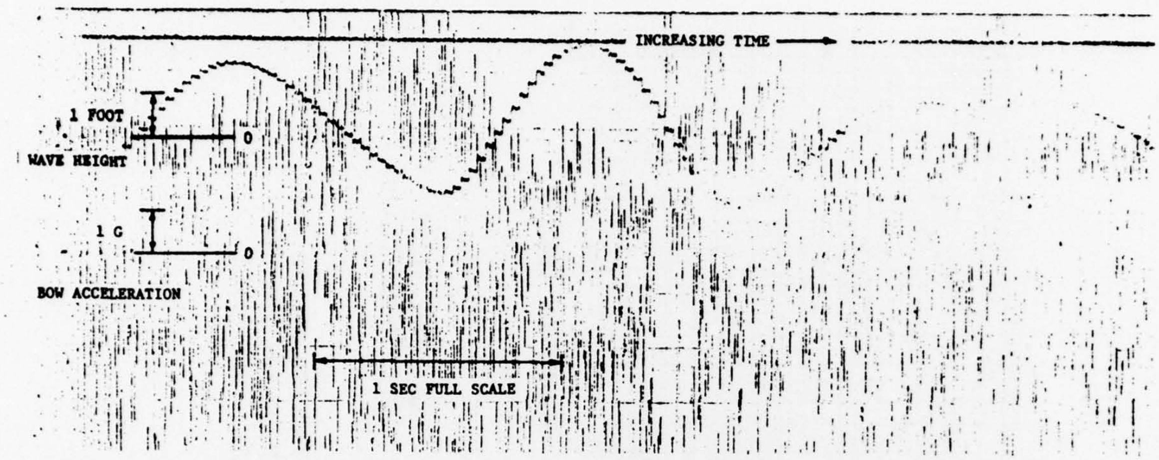
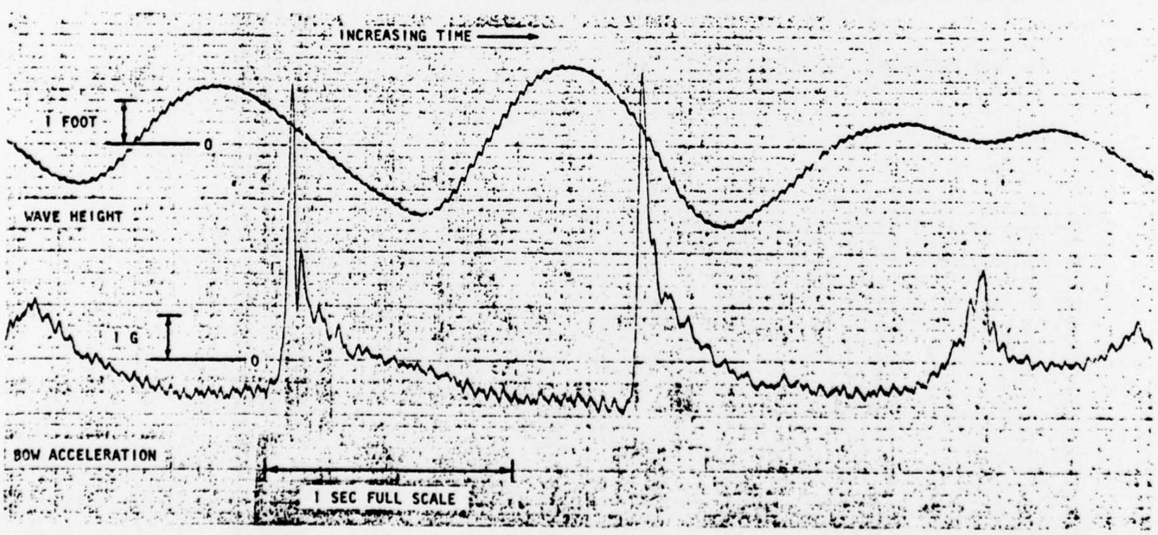


FIGURE 5g - NARROWBAND VERTICAL ACCELERATION INTENSITIES VERSUS STANDARD CENTER FREQUENCY OF THE ONE-THIRD OCTAVE BANDS AT THE BOW AND CG FOR THE LVA WITH AND WITHOUT CHINE FLAPS AT 0 KNOTS, BEAM SEA STATE 4 AND SWELL



UNFILTERED



100 Hz FILTERED

FIGURE 6 - SAMPLE TIME HISTORIES, BOTH UNFILTERED AND 100 Hz FILTERED, OF BOW ACCELERATIONS IN A HEAD SEA STATE 2 WITH THE SPEED OF THE NO CHINE FLAPPED CRAFT AT 30 KNOTS

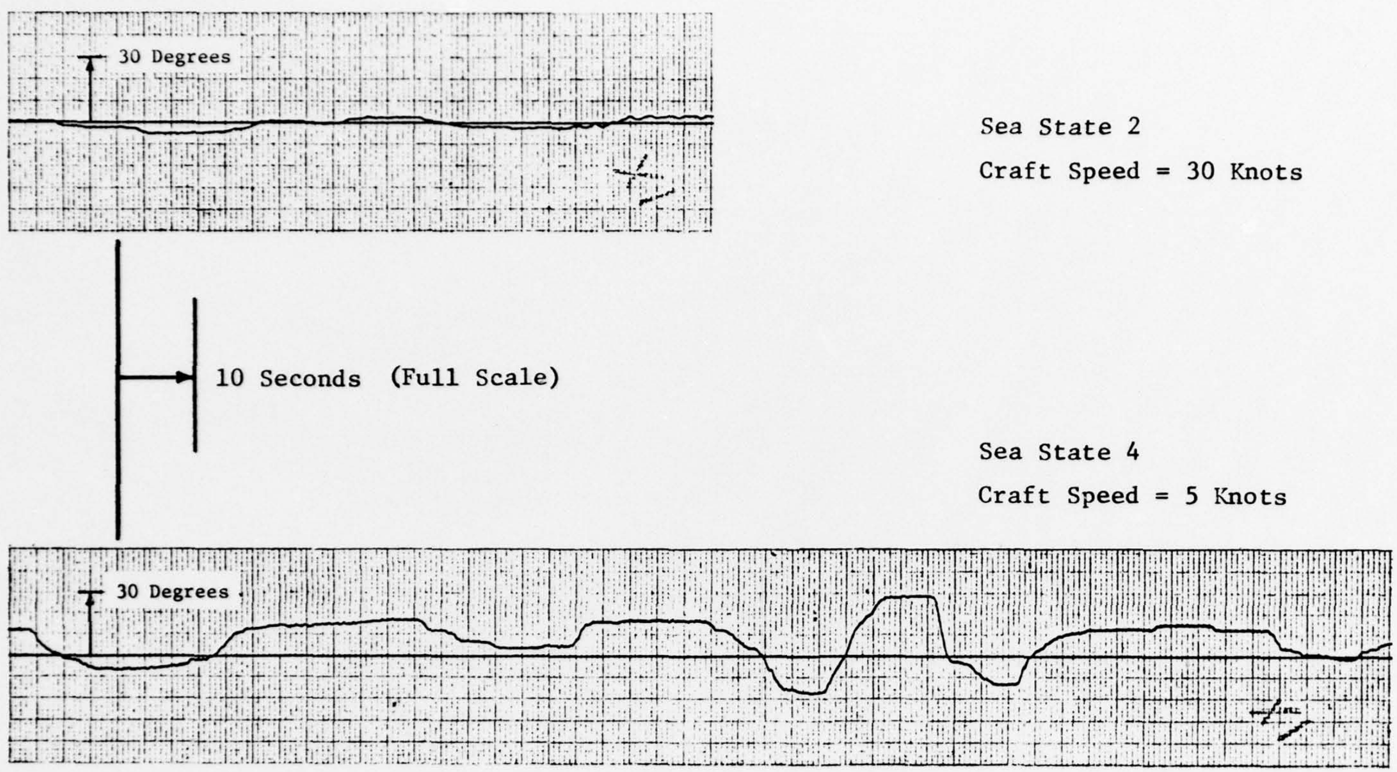


FIGURE 7 -- SAMPLE OF RUDDER ANGLE DISPLACEMENT OF THE LVA WITH CHINE FLAPS IN BOW SEAS

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